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The ADVANCEMENT OF SCIENCE

Vol. V, No. 19

THE PASSING WORLD

Presidential Address by

SIR HENRY TIZARD, K.C.B., F.R.S.

and

OTHER ADDRESSES

by

PRESIDENTS OF SECTIONS

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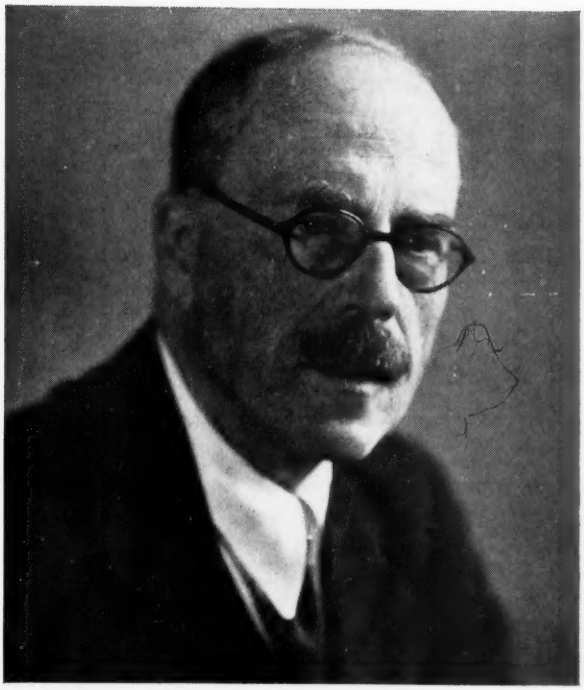

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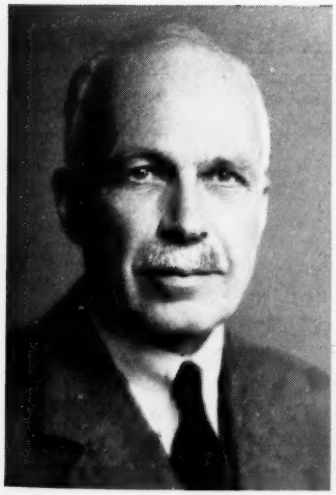

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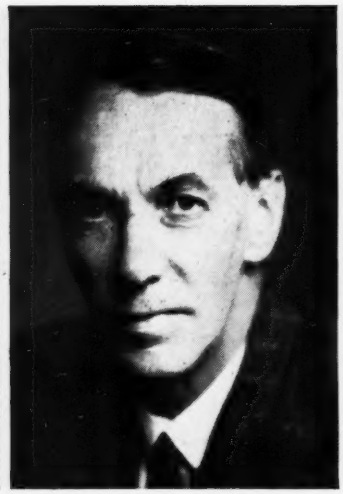

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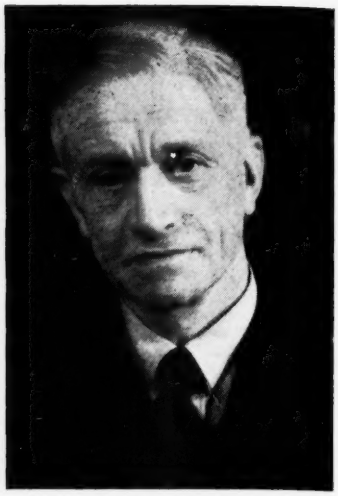

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THE ADVANCEMENT OF SCIENCE

VOL. V, No. 19 OCTOBER, 1948

CONTENTS

Addresses delivered at the Annual Meeting of the British Association for the Advancement of Science in Brighton, September 8 to 15, 1948.

PAGE

THE PASSING WORLD, *by* SIR HENRY TIZARD, K.C.B., F.R.S. 155

RECENT ADVANCES IN THE STUDY OF THE CRYSTALLINE STATE, *by* SIR LAWRENCE BRAGG, O.B.E., F.R.S. 165

SPECIALISATION AND CULTURE IN CHEMISTRY, *by* PROF. JOHN READ, PH.D., M.A., SC.D., F.R.S. 175

GEOLOGY TODAY AND TOMORROW, *by* DR. A. E. TRUEMAN, F.R.S. 184

UNDERGRADUATE ZOOLOGY, *by* PROF. H. GRAHAM CANNON, F.R.S. 194

GEOGRAPHY AS A SOCIAL SCIENCE WITH SPECIAL REFERENCE TO AFRICA, *by* RT. HON. THE LORD RENNELL OF RODD, K.B.E., C.B. 205

THE PRICE SYSTEM, *by* SIR HUBERT HENDERSON 210

THE YOUNG ENGINEER, *by* WING COMMANDER T. R. CAVE-BROWNE-CAVE, C.B.E. 218

FOLK-LIFE STUDIES IN BRITAIN AND ABROAD, *by* R. U. SAYCE 231

RECENT ADVANCES IN COLOUR VISION, *by* PROF. H. HARTRIDGE, F.R.S. 243

PRESENT-DAY TRENDS IN BRITISH PSYCHOLOGY, *by* PROF. REX KNIGHT 254

THE STUDY OF THE BRITISH FLORA, *by* PROF. J. R. MATTHEWS 262

THE CHANGING SCOPE OF EDUCATION, *by* MR. W. O. LESTER-SMITH, C.B.E. 272

AGRICULTURE AND THE WORLD FOOD PROBLEM, *by* DR. G. SCOTT ROBERTSON 277

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THE PRESIDENTIAL ADDRESS

THE PASSING WORLD

BY

SIR HENRY TIZARD, K.C.B., F.R.S.

SEVENTY-SIX years have passed since the British Association met in Brighton. Great changes have taken place in the world since then. Nothing illustrates the lapse of time more strikingly than one passage in the address of the President, Dr. William Carpenter. After referring to the expedition sent for the relief of Livingstone he added :

> ' While we give a cordial welcome to Mr. Stanley, let us glory in the prospect now opening, that England and America will co-operate in that noble object which—far more than the discovery of the Sources of the Nile—our great Traveller has set before himself as his true mission, the Extinction of the Slave Trade.'

And nothing better illustrates the truth of the old saying that the more things change the more thay remain the same than the address of the President of the section of Engineering, Mr. Bramwell. He discussed the coal problem. He drew attention to the alarming increase in the cost of coal, which had doubled in a year. ' I am aware,' he said, ' that the subject of coal is a hackneyed one,' but the startling facts to which he referred ' force us seriously to reflect upon the use and also the abuse of coal.' He discussed the inefficiency of domestic fires, but said he would rather put up with the whole of our present domestic discomforts, and even with the loss of heat than resort to the stove as a remedy. ' But let not users of coal remain indifferent to savings on their present consumption until those improvements are discovered by scientific men ; on the contrary, let them forthwith do everything in their power to reduce the consumption to the extent to which present science and, in some instances, present practice show the consumption can be reduced.'

At the same meeting the famous physiologist Professor Burdon Sanderson referred to the backwardness of physiological research in England as compared with Germany. 'If a man wants to be a physiologist ' he said, ' he must, as things at present stand, study medicine. There is no logical reason for this; for although medicine ought to be built on physiology there is no reason why a physiologist should know anything about the art of curing diseases.' However, it was a most encouraging sign of the times that Trinity College Cambridge had ' condescended to provide a place for physiologists to study and labour in, from which . . . one or two valuable researches have already sprung.' We shall all agree that the condescension of Trinity College has been amply rewarded. There is perhaps still room for similar acts of condescension on the part of wealthy corporations.

There is, finally, another passage in Dr. Carpenter's address which is of special interest to me. He describes how he urged on his friends in the Admiralty the importance of organising a new expedition to circumnavigate the world, and how the Royal Society followed up his preliminary enquiries with a formal request. The Admiralty agreed, and the good ship ' Challenger ' was then fitting out at Sheerness, and being equipped with the most modern scientific apparatus. Captain Nares had been chosen to command the expedition, and Professor Wyville Thomson to lead the scientific staff. The reason of my special interest is that my father was the navigating officer of that famous ship.

We are very happy, Mr. Mayor, to meet in Brighton again. Do you remember Macaulay's reference to Brighton in his famous description of the State of England in 1685 ? Just a hundred years ago he was writing these words :

> ' Brighton (in 1685) was described as a place which had once been thriving . . . but which was sinking fast into decay. The sea was gradually gaining on the buildings which at length almost entirely disappeared. . . . A few poor fishermen, however, still continued to dry their nets on those cliffs, on which now a town, more than twice as large and populous as the Bristol of the Stuarts, presents, mile after mile, its gay and fantastic front to the sea.'

I hope, Mr. Mayor, that the presence of the British Association on this occasion will render the famous front of Brighton no less gay, nor more fantastic.

'Verify your references' was the advice given by a former President of Magdalen, the saintly Dr. Routh, to an earnest seeker for guidance in his travels through life. The task of verifying the reference to Brighton in Macaulay's History led me very naturally to read the whole chapter again, and to refresh my memory of the concluding paragraph of the chapter :

> 'It may well be, in the twentieth century, that the peasant of Dorsetshire may think himself miserably paid with twenty shillings a week ; that the carpenter at Greenwich may receive ten shillings a day ; that labouring men may be as little used to dine without meat as they now are to eat rye bread ; that sanitary police and medical discoveries may have added several more years to the average length of human life ; that numerous comforts and luxuries which are now unknown, or confined to a few, may be within the reach of every diligent and thrifty working man . . .'

All, and more than all, that Macaulay foresaw, has come to pass. Indeed, all that the British Association set out to achieve over a hundred years ago, has been accomplished. Long past are the days when the public estimation of science had fallen so low that, to use the words of David Brewster in 1830, no scientist enjoyed 'the favour of his sovereign, or the friendship of his ministers ;' and when an alarmed Dean of York was moved to publish a pamphlet entitled, 'The Bible defended against the British Association,' which attained such a popularity with Victorian churchgoers that it ran through five editions in one year. We scientists have little to complain of now. The public estimation of science stands higher than it has ever done in this country. The Royal Society enjoys a prestige unequalled since the early part of the eighteenth century. The Great War, which has been succeeded by an uneasy peace, grimly demonstrated that the country whose rulers neglect science is lost ; and public men in England now display a touching but alarming faith in the power of science to solve any national problem, however serious. The time is near when, as Huxley warned us over sixty years ago, science, like Tarpeia, may be crushed with the weight of rewards bestowed on her. Let us then beware, when all men speak well of us, and be critical of ourselves. Let us ask whether we are claiming too much in some directions, and doing too little in others ; let us consider in fact whether the great forces of science, on the proper exercise of which all social progress depends, are in balance.

It was with some such thoughts as these that I chose the title of my address. It is taken from Dr. Johnson's well-known advice to the poor scholar in the 'Vanity of Human Wishes.'

> 'Deign on the passing world to turn thine eyes,
> And pause awhile from letters to be wise.'

I propose to pause awhile from the fashionable discussions of Science and the Community, Science and Education, and the like, and to invite you to turn your eyes on the passing world. For it is passing—from one state of unstable equilibrium to another. I say unstable, for many many years will pass before the dreams of those who look forward to a world Government which will bring not only peace but happiness to all, will come true. But if it must be in unstable equilibrium for many years to come, let us at least strive to balance it so that the chance of a major catastrophe is made as small as possible. Science has much to contribute to this aim ; but just as no man can aim a rifle accurately without a backsight as well as a foresight, so must we provide ourselves with both, if our contribution is to be worth while. The backsight is history ; it can be fashioned accurately by study. The foresight can only be fashioned from our knowledge of the state of science as it exists to-day, and from what we know is possible. It cannot be so accurate as we could wish, because we cannot foretell the effect of discoveries of which we have no inkling at present. My backsight shall not be too far back. In considering the future we shall not gain more by studying remote history than we gain perceptibly in accuracy by lengthening the barrel of a rifle. I shall sight, somewhat arbitrarily from the year 1885 ; not 1685. It happens to be a convenient year for me, as it was the year of my birth. It happens, too, that it marks almost the close of the stagnant period of nineteenth-century science, when many men thought that 'our power to discover new experimental facts was practically exhausted.' But new men were coming on, and new ideas were hatching. J. J. Thomson had just been elected to the Cavendish Chair of Physics at the scandalously young age of twenty-eight—a thing which would not be tolerated nowadays. Charles Parsons had patented the steam turbine in 1884, and demonstrated a model at the Inventions Exhibition in 1885. Gowland Hopkins had been appointed assistant to Sir T. Stevenson, the Home Office analyst, and was studying, in his spare time, the pigments of the wings of butterflies.

Three years were to pass before he was able to begin his formal education in science as a medical student at Guy's Hospital. Charles Sherrington was fighting cholera in Spain and investigating its causes, and Rutherford was carrying off all the prizes at school in New Zealand. Of these great men, whom many of us here had the privilege of knowing, only one is alive to-day. Sir Charles Sherrington is the oldest living President of the British Association. We send him our respectful and affectionate greetings.

It is understandable that none of these events, which in their different ways were to have a more profound effect on history and society than any legislation, or rise or fall of governments, created any public interest, except perhaps the exhibition of the turbine which was considered ingenious but wholly unpractical. In other respects the events of the year 1885 followed a normal course, judged by modern standards. There was fighting in what we now call the Middle East, which ended in the massacre of British troops, and of their leader, General Gordon. Our Russian friends were told that anxious though we were to preserve our friendship, there was a limit to patience. But the British public soon recovered from the shock of Gordon's death, and refused, so far as I can judge, to be seriously disturbed by the prospect of war. It must be remembered that they were denied the blessings of broadcasting, and other modern equipment for the ready circulation of bad news. They were far more exercised by the prospect of cholera spreading from Spain. They had reason for their anxiety, for the great majority remembered the epidemic of 1866 when 14,000 deaths from cholera were recorded. On the whole the people of England jogged along in a deplorable state of confidence, which was however justified by events, for nearly thirty years of peace followed, broken only by minor wars which had no perceptible effect on the growth of material prosperity.

In 1885, after a few years of depression, during which nearly 700,000 men and women left the country to seek better opportunities overseas, the United Kingdom was still the greatest manufacturing nation of the world. An enthusiastic commentator wrote at the time that 'the material greatness of the country is amazing—it exceeds that of any other Empire, Ancient or Modern. But the moral greatness is even grander. . . .' Unemployment was sometimes high in particular trades, such as shipbuilding, but between 1885 and 1914 it was never alarming, and was often as low as 2½ per cent. of the gainfully employed. The United States were not then serious competitors ; imports of iron and steel manufactures from the United States only reached an annual value of £500,000 in 1890, but from then on steadily increased. Germany was considered a more serious competitor. In the pursuit of science she stood first among the nations, and she was applying the methods and results of scientific research to industry on a scale and with a determination that far surpassed her rivals. At the meeting of the British Association in 1885 the President, Playfair, sadly recorded that in science 'Oxford and Cambridge are still far behind a second-class German University,' and that 'in Great Britain we have nothing comparable to the great technical college of Zurich.' Germany kept her pre-eminence in applied science until 1914 ; but it is perhaps worth noting that she never equalled the industrial prosperity of England, judged by the test of real national income. She might have done so, had not her rulers believed that by war they could find a short cut to the happiness and wealth that could have come in the natural course of events to a hardworking and highly educated people anxious to live in peace with the world. The terrible fate of Germany is a tragedy that affects us all, the last act of which perhaps we have not yet witnessed.

Many of the numerous comforts and luxuries which are now within the reach of every diligent working man in England are the result of invention or scientific discovery in or about the year 1885. I have already mentioned the steam turbine, which by making possible the generation of electricity on a large scale provided in the most convenient form the power on which industrial productivity so largely depends. Kelvin lit his house with electricity in 1881, and the telephone was invented in 1876 ; but they were both scientific curiosities in 1885. The modern 'safety' bicycle first appeared upon the roads in 1885 ; it was the manufacture of a reliable chain that made it practical. The first Dunlop pneumatic tyre appeared in 1888 ; but the idea was not then wholly new. Like many other things before and since, it had been invented before its time, that is to say, before manufacturing technique was sufficiently advanced to make it practical. Edison, in 1885, was in the full tide of his inventive genius. The first talking machine had been demonstrated in 1877, and in 1885 he was busy experimenting with motion pictures. Swan, whose share in the production of the carbon lamp is well known, invented a practical process for the manufacture of artificial silk in 1883. The typewriter in its early form was then quite old ; but difficulties in manufacture prevented it from becoming available in quantity until towards the end of the century. The internal

combustion engine which, in peace and war, has had a greater influence on society than any invention since that of printing, was developed from Otto's experiments in 1877. The intrepid Daimler drove a bicycle powered by an internal combustion engine of his own design in 1885; and the first motor cars were sold to the public. In the field of applied chemistry one far reaching development to recall is the electrolytic production of aluminium in 1885. Aluminium was then a rare metal costing £18 a pound. It now costs tenpence a pound.

Thus, although the science of physics was languishing until the discovery of the electron, X-rays and radioactivity in the closing years of the century, it was a time of enterprise and progress in engineering practice. The country prospered. In 1897, the year of the spectacular triumph of the Turbinia at Spithead, we exported goods to the value of one quarter of everything we produced. Ten years later we shipped overseas nearly one third of the whole national output of goods of all sorts—on farms, in mines, or in factories. If we were doing so to-day we should have little cause for anxiety. Perhaps it was this very prosperity that caused us to fall behind in some branches of industry, for when there is little unemployment and when the standard of living is obviously rising in all sections of the community, there is an excusable tendency for manufacturers to go on doing what they know they can do successfully, rather than to launch out in new directions. Is not this, rather than the neglect of science, the chief reason for the fact that synthetic dyes and fine chemicals were manufactured in Germany, rather than in their original home of England? Whatever the answer to this question, the fact remains that when war started in 1914 we were caught off our balance. We found ourselves dependent on our enemies for many essential products and instruments on which our power to make war, and to maintain health, depended. But, to everyone's surprise, we also found that the reserve of scientific ability in the country, though not large, was high enough in quality to overcome the immediate dangers with remarkable speed. Young men from the universities who had spent their time on researches of no practical importance applied themselves with success to problems often completely outside the range of their previous studies. We had the same experience in the late War, although fortunately we also had the foresight to prepare for some of the worst dangers beforehand. There is a clear lesson, I feel, to be drawn from this experience. Whatever may be done, in a burst of public enthusiasm, to support and promote schools of research at Universities, nothing should be allowed to lower the quality. And size, beyond a certain point, undeniably does. A research laboratory, of whatever nature, is like a living cell. Once it reaches a certain size, which may differ with the nature of the subject, it must divide or die. When a young graduate tells me, as one did recently, that he was going to do research because it got him off military training, it makes me wonder whether we are not already overpopulating the research departments of Universities.

The shock caused by the exposure in 1914 of our industrial shortcomings, which had been concealed by the apparent prosperity of previous years, led to a great increase of research by industry and by Government. The National Physical Laboratory, which had been of inestimable value during the war, extended the scope of its work. The Department of Scientific and Industrial Research, which was founded in 1915, established other Government Research laboratories, and encouraged the formation of research associations to serve the needs of the older scattered industries. University schools of science were greatly enlarged, and under the influence of the great men of the inter-war period there was a surge of discovery which put Great Britain in the van of progress in nearly all branches of science. We became a scientific nation. The newer industries, such as the viscose and radio industries, which had been founded on science, rapidly developed. The chemical industries took on a new and active lease of life. Germany, badly disorganised by defeat, ceased for many years to be a serious competitor in the world market. Many of us must have felt confident that when leadership in scientific and industrial research was allied to experience in commerce and manufacture, and to skill in craftsmanship, our country would have little difficulty in maintaining its position among the nations of the world. We have been disappointed. I am referring now not to the acute difficulties of the present day, but to the general trend of events before and after the first world war, when in spite of a nearly continuous advance in national income and standard of living, Great Britain gradually lost her pre-eminent position. We cannot attribute this relative decline to the 1914 war. That war had curiously little effect on our economy. Nor can we attribute it to the world depression in the 1930's. The depression affected us much less than many other nations, for owing to the great fall of prices of food and raw material the terms of trade moved sharply in our favour. From 1930 to 1938 the volume of exports necessary to purchase a given volume of imports was only two thirds of what it had been from 1885 to 1914. To what then shall we

attribute the relative decline? Shall we argue that a main cause was that research was on too small a scale, or shall we seek for other reasons?

Let us first be clear about what results we expect to come from the application of science to industry. The primary object of industrial research is severely practical. It is not to enlarge the boundaries of knowledge, or to publish scientific papers, although that may be a prerequisite or a consequence. The object is to do something that has never been done before, or to do things better than they have been done before. And it has, or should have, the special object of reducing the labour required to supply the material needs and wants of men. All social progress such as spread of education, promotion of health, opportunities for leisure and healthy recreation, must depend on the power of science and technology to increase the productivity of industry. The rate of social reform is set by the rate at which productivity increases; and social unrest is inevitable if reform lags too far behind the advance of technology, or is pressed too thoughtlessly before it. So we must judge the effect of industrial research not merely by the new comforts and luxuries that it produces, but also by the rate of improvement of existing processes. In our country, which depends more than any other on international trade, and which can continue to maintain its present population only by exchanging manufactured articles for food and raw materials, the productivity of labour is of primary importance, for unless it is as high as, or higher than, in other manufacturing countries, we shall not be able to compete in the markets of the world. And the productivity of labour in our country is far lower than it could be if the results of past research were more resolutely and continuously applied. We find this particularly in certain industries of great importance. In the coal industry the results are painfully obvious—the coal raised per man employed is now lower than it was thirty years ago, when nearly all coal was hewed by hand. Research on building has been intensively pursued since the Department of Scientific and Industrial Research was founded. Those responsible for its direction have not been content with the publication of papers giving the results of their investigations but have built demonstration houses for other builders to inspect and study. But are better houses now being built with less labour than twenty years ago? I doubt it; if not, the research has had as yet little influence on practice. The Shirley Research Institute for the Cotton Industry is well known for the range and excellence of its work; but productivity in the cotton textile trades is lower than it was fifteen years ago and much lower than in some other countries. Taking British industry as a whole, productivity is far lower than in the United States. In both countries about 40 per cent. of the population is gainfully employed. In the United Kingdom the proportion engaged in manufacturing, building and civil engineering, which covers the production of all capital and consumer goods (other than minerals or food) is now a little under 18 per cent. of the population. In the United States the corresponding figure is 12 per cent.; and yet in proportion to the population the volume of production is far higher than in the United Kingdom.

The causes of the relative productivity and wealth of nations are, of course, many and complex. We gained our supremacy in the nineteenth century because we excelled in engineering genius and were the first to use mechanical power on the large scale for manufacture and transport. Our population grew rapidly because we were prosperous, and it paid us to become a food importing nation because the productivity of labour in the secondary industries was so much higher than in agriculture. But conditions have changed in the course of time. We no longer have any outstanding natural advantages, and we must expect that given approximately equal skill in technology other nations with greater natural advantages will surpass us. Only by maintaining leadership in the application of science can we hope to keep our position among the great nations. So it is not surprising that the United States, and Canada, for example, with their great natural resources, and abundant supply of cheap power, should have passed us in wealth and productivity before the War. It would have been surprising if they had not. But it is by no means so easy to explain why Switzerland, which in 1885 possessed a national income per head about two thirds of that of the United Kingdom should have equalled us in prosperity by 1939; or why the industrial productivity of Sweden, a country that has no coal, should have been rising so much more rapidly than ours in the years between the wars. These two countries cannot be said to possess natural resources superior to ours; nor can it be argued that in the quality or quantity of scientific and industrial research they excel us. But I suggest that they, in common with the United States, possess a higher average standard of technology than we do, and have a much greater proportion of men of high scientific education in executive control of industry. I quote them in support of my view that it is not the general expansion of research in this country that is of first importance for the restoration of its

industrial health, and certainly not the expansion of Government research remote from the everyday problems of industry. What is of first importance is to apply what is already known.

The fact is that all really new developments of industry are the product of the work of very few men. In general, knowledge in the physical sciences now accumulates at a rate much faster than it is, or possibly than it can be, applied in industry. There is a vast amount of knowledge waiting to be used. No new discovery, in any field, is likely to have so quick and beneficial an effect on British industry as the application of what is already known. We hear, for example, of the possiblity of the production of power from atomic sources of energy. I do not think that anyone will be rash enough to prophesy what discoveries of real industrial importance will result from the researches now in progress ; but I shall certainly assert that the production of power from uranium cannot bring such economic benefits to this country within twenty years as would the practical application of known methods of economising coal. Mr. Bramwell's advice in 1872 is still sound, and is always likely to be. Even in those fields of industry where science and development have been most in step we find scientific knowledge far ahead of practice. In aeronautics, for example, research has shown, without any shadow of doubt, that it should be possible to design aircraft far more economical in fuel consumption than present aircraft. For the next step we need bold and highly skilled engineering rather than more fundamental knowledge : if it is successful, air transport, instead of existing precariously on subsidies, will compete on level terms with the train and ship for long distance passenger travel. Indeed, a revolution in transport is in sight. Shall we leave it to be encompassed by other nations, or shall we show the way ? The answer depends on whether we shall encourage enterprise and adventure in engineering.

Although I have been interested in the problems of industry for many years, I have never been closely concerned with its conduct. But for much of my working life I have been intimately concerned with that peculiar business called war, which is as old as agriculture, which is subject to the most violent booms and slumps, the cause of which we do not understand, and in which the incentive to succeed is greater than any profit or ideological incentive in civilian life. There is a healthy human rivalry between the various units and companies into which the business is divided. Sometimes it may be thought that this rivalry is carried too far ; but all are working for the same cause. In my own lifetime I have seen this business change from one in which the practical man considered he had little to learn from scientists, into one in which scientists are concerned with its every aspect, from policy making, to the actual conduct of operations. We shall all hope that this business is moribund, and shall do our best to kill it : but in the meanwhile it is possible that other old industries have much to learn by studying the principles of its successful conduct.

In the first place let us note that the managing directors, the Chiefs of Staff and Commanders, are all carefully selected highly trained professional men, who have gained their experience in a hard school, and who, at intervals in their career, have had the opportunity to study, at Staff Colleges and elsewhere, the fundamentals of their trade. The managing directors do not have the final responsiblity for policy, but have a great influence on the decisions. Secondly, the technical efficiency of the business is entrusted to a body of engineers and technologists, who have had an advanced specialised education and experience, and who are in personal contact at all levels with scientists who are concerned with research and development. This secures that in all research, however recondite, there is a practical objective, and that there is also a continuous urge to improve in detail. The scientist is primarily responsible for research, but experienced engineers take part in it. The engineer and the scientist are jointly responsible for development. But there is no part in the whole process from research to production and use that is neglected and none in which scientific thought and influence is wholly absent. One point of special interest is that far more attention—but perhaps still not enough—is given to the study of man in relation to the machines he has to operate than in any branch in industry.

It does not need any profound research to show that the British industries that are now best standing up to the strain of adverse circumstances are those that most nearly approach the system I have described. The chemical industries, for example, have gradually developed a similar organisation over the last thirty years. Neither research nor development has been neglected, and management is in the hands of men highly educated in pure and applied science. The result is that our chemical industries are a source of great and growing strength in peace and war. Forty years ago they were far inferior to the German industries ; now they have little to fear from any competitors. In the steel industry, whose efforts now merit our admiration, it is not uncommon to find management and direction entrusted to men

of the highest reputation in science and technology. Turn your eyes on any industry in the world that is similarly organised, on the steel industry of Australia, for example, or the photographic industry of the United States, or the machine tool industry of Switzerland, and you will find that they are the best able to weather the storms and take advantage of the fair winds of trade. And I shall ask you to note that in such industries human troubles, if not entirely absent, are inconspicuous. This, I think, is to be expected, for most men are happiest and do their best work when new things are being attempted, and when adventure of some kind relieves the monotony of a daily routine.

It is a mistake to suppose that science advances rapidly in a war. Certain branches of science may receive a special stimulus, but on the whole the advance of knowledge is slowed. What is striking in a war is the rapid solution of practical problems by the use of previously acquired scientific knowledge and technique. It is a mistake also to attribute this success to the fact that cost does not matter. Cost matters a great deal ; indeed the purpose is always to achieve the end in view with the minimum cost of lives, labour and material. And, finally, all depends on good design and production. Our weakness in the War was not to be found in the judgment of what was best to do, nor in the scientific work necessary to do it. It was when the stage of design and production was reached that we fell short of the best standards. For example, penicillin, the greatest practical achievement of medical research during the War, was a product of British research ; but unless American skill in large-scale manufacture had been available, many thousands of men, who now enjoy a healthy life, would have died.

We now see history repeating itself. After the second World War, as after the First, there is a cry for more research, in industry, and by Government, and a strong demand on the Universities to expand their schools of science. Temporarily this enthusiasm is having an unfortunate effect, for the schools are getting starved of teachers ; and unless a high standard of teaching is maintained in our schools, the next generation of scientists will suffer. In the long run, too, the expansion of research will fail to produce the hoped-for result unless we promote at the same time education in the higher branches of technology, and unless the technologist takes his rightful place in industry. Throughout the nineteenth century, the advances in engineering that made so great a difference to our prosperity, were the product of inventive rather than of scientific genius. Even the steam turbine, though its conception was founded on long established physical principles, was brought to a high pitch of practical efficiency with very little assistance from scientists. But we live in a different age. Pure invention still has its place ; but industrial prosperity will depend more and more on the continuous application of science to industrial practice. Unless we can raise our standard of technology, unless there are many more men in executive positions in industry, whose practical experience has been preceded by a scientific education, we shall inevitably fail to keep our place among the great manufacturing nations. President Playfair's remark about Oxford and Cambridge is no longer true. Cambridge has long been recognised throughout the world as a great home of science ; and it is not merely devotion to my Alma Mater that prompts me to say that Oxford is now not far behind. But I fear that it is still true that in this country we have nothing comparable to the great technical college of Zurich.

I turn now to another branch of applied science, less spectacular in its results to the ordinary citizen, but far greater in the benefits that it has brought to mankind during the last sixty years. The physical sciences have given men comforts and luxuries that are obvious to all. The aeroplane, the cinema, the broadcasting and television receiver, the domestic refrigerator, and many other familiar things which were unknown even at the end of the nineteenth century, are positive results of scientific research. Health, on the other hand, is in a different category. The ordinary citizen sees little connection between the advance of science and the fact that he is healthy ; it is, he feels, a quality that other people may lack, but is his by right of a superior heredity or habit. Ill health, on the other hand, while a fault in other people, is a misfortune in himself, and a serious reflection on the state of medical science. How many men now living in this country have any real conception, I wonder, of the astonishing advances in the prevention and cure of disease that have taken place in the last sixty years, and of how they have come about? Where is the cholera with which I was threatened as a child if I drank unboiled water? Its last appearance in England was in 1893 ; it was soon stamped out, and there has been no epidemic since. We are puzzled and alarmed by its appearance even in a country like Egypt, with its low standard of sanitation. Many other diseases which were common in 1885 have practically disappeared or are under control. Those that remain, will, without doubt, be conquered in the end by the advance of knowledge.

In 1885 the crude death rate was twenty

per thousand ; now it is twelve. In 1885 one in every seven children died during the first year of life ; now the figure is one in twenty-five. In 1885 a young man of twenty could expect on the average to live for forty-one years ; now his expectation of life is forty-eight years. And it is not merely that he will have a longer existence, but that he can look forward to a far healthier life. Where can one now find the stunted children with distorted limbs, who were a common sight in the industrial towns of England when I was young ? If it were possible to compare a random sample of young men and women from the poorer districts of London with their grandparents at the same age, it could hardly be believed that they came from the same stock. Only those few doctors who had the duty of examining recruits for the Army in the 1914 War and in the last War can have any vivid appreciation at first hand of the changes that have come about in a single generation through the study of nutrition and preventive medicine.

These great advances have been mainly due to the fundamental researches of very few men, and to the vigour and good judgment with which their work has been extended and applied in practice. Never has public money been better spent than on this branch of applied science ; and never has such a small investment yielded such a rich return to the nation. The recently published report of the Medical Research Council, covering the war years 1939 to 1945, is a document of the highest scientific and historic importance which can be read with interest and profit even by laymen who are unfamiliar with the jargon of medical men. In 1939 the Medical Research Council confidently stated that—

> 'The destructive power of arms will indeed have increased immensely since 1918 if it overshadows the advances in knowledge for the saving of life which modern discovery has placed at the disposal of medical men. If a strict comparison were made between what science has done to increase war mortality and what medical science has done to lessen these lethal effects, there is good reason to believe that the latter would be an easy winner.'

Omit the word ' medical ' in the last sentence, and I think that you will agree that no prediction has been more amply justified. Nor should we too quickly assume that new destructive weapons evolved by physical science will in the future reverse the decision. In spite of all the hazards of bombing, the average civilian death rate during the years of war was lower than it was during the immediately preceding years of peace. The deaths in the fighting services were less than one third of the deaths in the 1914-18 War ; and over 80 per cent. of the wounded have been restored to normal life. And in spite of all the difficulties caused by the submarine blockade, and the shortage of food, which still persists, we are a healthier nation than we were in 1939. Whether we are as energetic is another question.

Our American allies have the same tale to tell. Four years of hard fighting in Europe and the Pacific caused fewer deaths than in the American Civil War, when the population of the United States was only one fourth of what it is now. It was only in Germany, East Europe and Russia that war counted its victims by millions, and then not through the destructive forces of science, but because of the brutality of human nature at its worst.

Nevertheless the progress of preventive medicine is giving rise to social changes of great complexity, which will seriously affect the peace and prosperity of the world unless their consequences are studied with care, and their possible evils counteracted by wise and far-sighted action. In all countries which have a high standard of education, such as our own, the rise in population which follows a rapidly decreasing death rate has been kept in check by a voluntary control of births. As a result the average age of the population has considerably increased, and is increasing ; the proportion of the population of England and Wales that is over sixty-five years of age is now nearly four times as high as it was in 1885. This in itself, does not yet present any serious problem, for, as the proportion of children is much less than it was, the proportion capable of productive work, between the ages of fifteen and sixty-five, is actually somewhat higher than in 1885. No fundamental difficulty, from this cause, is likely to arise for many years to come. But the population of the world as a whole is now increasing by 1 per cent. a year, and its distribution is such as to make it extremely doubtful whether the supply of food can keep pace, even with the present low standard of nutrition. It is the advance of science that has made this possible. War, pestilence, and famine have kept the population within bounds since the dawn of history. War has ceased to be effective ; pestilence is rapidly losing its power ; only famine is left as a brake until education takes its place. Is famine inevitable, or will science again come to the rescue, as it has done before ? I do not think that the danger of the present position is yet fully realised, in spite of all the work and publications of the United Nations Organisation, and in our country the well-

informed debates and warnings of the House of Lords. People remember only too well the apparent over-production of food in the 1930's, and forget, or do not know, that since then the population of the world has increased by some 300 million people.

A single example of what is now happening, and will probably happen on an ever-increasing scale, may help to illustrate the problem. Malaria has always been one of the most potent instruments of population control. It is endemic in most tropical countries. In the Far East it has hitherto been an antagonist more to be feared than the armed forces of an enemy. In the late war it was defeated by the controlled use of mepacrine, a German drug, which is being replaced by an even better product of British research. In addition, the potential importance of the insecticide D.D.T. for the elimination of malaria-carrying mosquitoes began to be recognised toward the end of the war.

In 1944 Sir Robert Robinson, Professor Simonsen, and Dr. King visited British Guiana on a special mission. British Guiana has a population of roughly 400,000. Accurate statistics of the fluctuation of population do not exist, but it is probable that it has remained stationary for the last twenty years. Two thirds of the population used to live under conditions of severe endemic malaria. The birth rate was low, and the infantile and adult mortality high.

The particular type of mosquito which is the carrier of malaria, and also of yellow fever and filariasis in the Colony, lives and breeds in the wooden houses, and not in swamps. It is thus peculiarly susceptible to attack by insecticides. The British mission advised a comprehensive trial. They were fortunate in finding a most experienced and progressive officer in Dr. Giglioli, Honorary Government Malariologist. Their advice was taken ; operations were started in 1945, and at the time of speaking it is probable that the whole population of the Colony has been protected. The annual cost of keeping the whole district under continuous control is of the order of five shillings a head.

Malaria is now rapidly disappearing from the Colony. I cannot quote valid statistics covering the whole population, but I have been supplied with exact information about a suburb of Georgetown with a population of about 3,000, and there is no reason to suppose that the results will not apply generally. In this village the death rate was equal to the birth rate during the years 1938-1944 inclusive. The average infantile mortality during this period was about 250 in a thousand. It rose to over 350 in 1944. D.D.T. control was introduced in July 1945. By the end of 1947 the birth rate had doubled, and the infantile mortality had dropped to 67 in a thousand. The population is increasing by 10 per cent. annually.

As the new methods of preventive medicine spread—and that there will be many more to come no one can doubt—we must expect the world population to grow at an even faster rate than it has done in our lifetime, unless famine intervenes. And it will grow particularly in parts of the world that already have a high density of population, such as India, where the population is now increasing by five million people a year ; and Egypt, where there are already 2,000 people to every square mile of cultivated land, and where it pays to have children as they are a source of labour and of profit to their parents at a very early age.

Exactly fifty years have passed since a President of the British Association last warned his audience of the danger of famine. Sir William Crookes was then alarmed at the prospective shortage of wheat. He produced evidence to support his conviction that England and all civilised nations stood ' in deadly peril of not having enough to eat.' But he qualified his gloomy forebodings by the statement that the chemist must come to the rescue of the threatened communities, and went on to discuss the possibility of the fixation of nitrogen. If that were achieved, the future, said Crookes, could take care of itself, and ' in days to come when the demand may again overtake supply, we may safely leave our successors to grapple with the stupendous food problem.' The chemist did come to the rescue, and the plant breeder too, though not quite in the way that Crookes imagined ; and now the day has come when we must grapple again with the problem. We must not encourage the easy thought that some entirely new development in science will solve it quickly ; there is nothing in sight comparable with the importance of synthetic fertilisers. There are certainly some interesting investigations in progress, for instance the production of food yeasts from molasses, and of fats by the action of micro-organisms on carbohydrates. All that can reasonably be said about these new developments at present is that they show the need for fundamental research in an almost untouched field. They are very unlikely to lead to a new and substantial source of supply of food within the next thirty years. So far as this country is concerned we must plan our economy on the assumption that food will be both scarce and dear for many years to come. Its scarcity is obvious to us ; its dearness is concealed by a policy of subsidies. I do not criticise the policy. I refer to it only because it tends to hide a state of affairs that should be realised by every thinking man.

One or two years of good harvests in the wheat producing countries may go far to relieve the present troubles of Europe, and will be of great benefit to us. But the supply of wheat is only part of a larger problem. World food supply will only keep up with demand if the productivity of land is increased, and more land is brought into cultivation. The productivity of land in the United Kingdom is already high ; much higher, for example, than in most European countries and in North America. The productivity of labour on the land has increased in recent years much more than the productivity of labour in any other old industry. One man working on the land now produces enough food for twenty-five of the population. New Zealand surpasses all other countries in both respects. It is a land blessed by Nature and improved by science. But few people realise that in our small country we now grow enough food for twice the population of Canada. There is still room for a great advance. There is a consensus of opinion among experts whom I have consulted that the production of food in the United Kingdom could be raised by 20 per cent. within five years by a combination of measures, such as the improvement of grasslands, the conservation of grass for winter feeding, the control of pests and weeds, the extended use of fertilisers, and the development of large tracts of marginal land such as exist in the Highlands of Scotland. It is argued that, though this would need considerable capital expenditure, there is no direction in which capital expenditure would yield more certain dividends to the nation, or make a more substantial contribution to the balance of trade.

I find these views convincing. But even if all this were to come to pass, we shall still need to import food for twenty to twenty-five million people unless there is to be a large outward movement of population ; and we must not lose sight of the fact that at least twenty million people are added to the population of the world every year, and that it is conceivable that in another seventy years, or even less, the world population will have doubled. Whatever other countries may do, it is our bounden duty, and the only certain way of safeguarding our future so long as we remain a large food importing country, to develop our Colonial territories, particularly the underpopulated African Colonies, where the increase in population that would follow the control of disease and the increase of food supply would open fresh markets for international trade. This great task will call for the intensive application of science, in collaboration with other countries. The tale of plant disease in our Colonies, for example, is a sorry one. I shall predict that unless the prevention of disease among plants and animals, and all other scientific problems of the supply of food, are studied on the same kind of scale, by men of similar calibre, as are the problems of human health, chaos and misery will result. Whatever new comforts and luxuries may be provided in future by the advance of physical science, it is on the development of the biological sciences that the peace and prosperity of the world will largely depend. Until recently there have been far too few careers open to young biologists outside the field of the medical sciences. There has been nothing corresponding to the Colonial Service, which has offered to young administrators a life of adventure nicely seasoned with economic security. All members of the British Association will therefore welcome the intention of the Government to inaugurate a Colonial Scientific Service, and will hope that the conditions of service will be such as to attract young men of the highest quality.

We live, indeed, in difficult times. But they are very interesting times ; and difficulties are bracing to a nation which has not lost the resilience of youth. We must not get into the way of thinking of our great country as an elderly man who is told by his doctor that if he is very careful of his diet, and avoids all exertion and worry, he may look forward to some years of placid life before he dies. This is a time for adventure ; for taking risks. Calculated risks, of course ; but not so nicely or so lengthily calculated that they are taken too late. My contacts with Universities and with industry are not now so frequent or so close as I should like them to be ; but they are enough to convince me that the spirit of adventure in science is as lively as it ever was. It is that spirit which will largely determine the future. Many years hence, when a President of the British Association reviews the progress of the nation from the depths of bankruptcy to new and unsurpassed heights of prosperity and influence, he may well have occasion to refer, as I did at the beginning of this address, to the great influence of the work of a few young men, who are now unknown to the public ; and he may justly claim that the chief cause of the change was that we had found the right way to combine originality in science with enterprise and speed in its application.

SECTION A.—PHYSICS AND MATHEMATICS

RECENT ADVANCES IN THE STUDY OF THE CRYSTALLINE STATE

ADDRESS BY

SIR LAWRENCE BRAGG, O.B.E., F.R.S.

PRESIDENT OF THE SECTION

1. I feel it to be a great honour that you should have chosen me to be the President of our Section A this year. It is a mark of your esteem to which I shall always look back with pride and solid satisfaction. There are certain events in the career of any man which stand out as landmarks, as evidences of the support and sympathy of his fellow workers, and this is certainly such an event in my career. I suppose that everyone must feel, as I do, the very different aspect of one's life-work when viewed from the front or from the back of the stage on which we play. We try to put up the best show we can to the audience, but as a player we see the scenery from behind with all its desperate make-shifts. We are conscious of how far our achievement has fallen short of what we have tried to do. I confess to a feeling of mild surprise when I see my name on the bills, especially when it appears in such a galaxy of talent as that which graces the list of former Presidents of this Section. It is a particular pleasure to me that I am following one who is by no means the least famous of the holders of this office, and who has been a lifelong friend and colleague. When I was starting my career of research, a young John's student called Edward Appleton was the first whom I ever had to work with me. We investigated the structure of metal crystals together in 1914. Had it not been for the war, who knows but that he might have made as great a name for himself in crystallography as he has in his chosen field. Fortunately for our knowledge of the behaviour of radio waves and the structure of the upper atmosphere, his genius was bent in other directions. When I returned to Cambridge in 1938 he was my fellow professor in the Cavendish Laboratory, where he had built up such a unique school of radio physics. He has bequeathed this school to us, and I always feel it a trust to see that it is fostered and helped to the best of my ability. I think it can be claimed that his inspiration still has an opportunity to show itself at Cambridge, and that the younger people under the direction of his pupil Ratcliffe are producing fascinating new developments which are worthy of the traditions he established.

It is natural for me to choose as the subject of my address the field of X-ray analysis of crystals, in which I have always worked. The accidents which determine the nature of any man's scientific investigations have always interested me. A main factor in my own case was my father's interest in the nature of X-rays, because he so often discussed with me the significance of Laue's discovery of X-ray diffraction in the summer vacation of 1912. I doubt, however, whether this would have been more than a passing interest of mine had it not been for some contributory factors during my time as a student at Cambridge. Our lecture courses at that period only partly covered the field of physics, going intensely into some branches and leaving others quite untouched ; they were very different to the conscientious reviews of the whole subject represented by Honours courses in universities to-day. They did, however, leave us a good deal of time for reading, which I know I pursued in a very desultory and haphazard way. But one course particularly fired my imagination, the course on Optics given by C. T. R. Wilson. It was not a very easy course to follow, because the blackboard often heard a good deal more of the lecture than we students did, but his way of thinking about optical problems had the qualities of style and grace. It was like being shown how to produce a stroke by a master of a game ; he taught us the technique of scientific thinking. He was also in charge of the practical classes. Like all young students, I was keen to ' finish ' an experiment and go on to the next. C. T. R. was too gentle and kindly ever to suggest we might be wrong or had skimped our work, but by a series of apologetic and hesitant comments we were somehow made to feel that there was a great deal

more to it and that we had better try all over again. I would like to take this opportunity of paying a tribute to one whose teaching must have profoundly influenced, directly or indirectly, the physics courses in most of the universities in this country, for many who are now in responsible positions have been his pupils. He gave me a love for physical optics which was a major influence in deciding me to research in X-ray optics. Another factor, which illustrates the part chance plays in deciding one's line, was a particular meeting of a very small and informal society in Trinity formed to discuss scientific papers. The subject of one of these papers was the Pope-Barlow theory of valency-volume, according to which atoms packed together as if they were spheres with a volume proportional to their valency. The theory was wrong, but our talk occurred at about the time Laue's discovery was made, and it made me think about the geometrical ways in which atoms could pack together in the solid state. Nowadays most scientists have some acquaintance with the three-dimensional geometry of crystalline arrangement, because so much light has been cast on physical and chemical problems by the successes of crystal analysis. At that time, hardly anybody except a few isolated enthusiasts had given it a thought. Barlow was one of these enthusiasts. His pictures of close-packed atoms were a fertile source of inspiration, and just supplied the missing link in understanding the optics of X-ray diffraction. It has always been a lesson to me in the value to young students of small scientific societies where they themselves give the papers, especially when they spread themselves over a wide field. Science is so rich and unexpected in its surprises that one never knows what odd bit of information may supply the necessary clue to the solution of a problem. I wonder sometimes if we are not too efficient nowadays in planning well-rounded and comprehensive courses which demand all of our students' time and energy, leaving them little opportunity to browse in less specialised regions. In my case, at any rate, it was this interest in Barlow's geometrical constructions which led me to seek a new interpretation of Laue's diffraction pictures, and so to the idea that they revealed the arrangement of the atoms in crystals.

2. Sir Edward Appleton recently asked me to quote some examples of new achievements in science and technology which have been the direct result of X-ray analysis. I confess that I found it a hard question to answer. In the case of such discoveries as that of the electron by J. J. Thomson, or the nature of the nucleus and its disintegration by Rutherford, one can at once point to a new physics and a new technology which has been or will be made possible by them. The analysis of the arrangement of matter by X-rays has had a far-reaching influence, but one of another and less direct kind. No new fundamental particle has been revealed by the X-ray microscope. The information it has provided has been of a type which one might have predicted in a vague and uncertain way. What it has done has been to replace guesses by accurate and precise knowledge of atomic architecture in matter, and this has led to its having a profound influence on all the physical sciences. It may well in the near future have an equally great influence on the biological sciences. I count myself fortunate in that my subject has been one which has taken me into so many fields, and involved collaboration with colleagues in so many branches of science. Mineralogy, inorganic chemistry, organic chemistry, metal chemistry, metal physics, colloid chemistry, biochemistry—X-ray analysis has had as close a connection with these sciences as it has with experimental and theoretical physics. In each case former ideas have been modified and clarified, and new lines have been opened up, by our now being able to see the precise way the atoms are related to each other in space.

In my own subject of physics there is a parting of the ways at the present time. The main principles of atomic structure, the great puzzle in the early years of this century, have been discovered. Though the complexity of the problem still often defeats a close quantitative analysis, we can understand the nature of the forces which bind atoms together into chemical compounds and these again into larger-scale structures. One great army of physicists is being lured on to explore the mysteries of the fundamental particles, working in the fields of nuclear physics and cosmic rays, and building machines for their experiments whose size is in inverse ratio to that of the bodies they are examining. But there is another great field of physics which has equal attractions. Starting with our ideas about the structure of the atom, we can go back to classical physics, to what used to be generalised as the ' properties of matter ', and interpret them anew in the light of our new knowledge. This is the field to which I have always been attracted. I consider it important that when they come to choose their researches, our young students of physics should realise that there are problems here as difficult and as fascinating as those of nuclear physics. Their importance to industry is as great as their scientific interest. This is an age of new materials, and we must attempt to understand how the properties of matter in bulk are determined by its atomic construction.

3. Our country has played a leading part in the development of X-ray analysis from the first. Doughty exponents of this art are to follow me this morning, and give an account of their recent researches. But we now have so many centres of X-ray analysis in this country that it has been no easy task to choose a team to play for the side. Most of our experts came originally from three schools of research, my father's group at the Royal Institution, the Crystallographic Laboratory at Cambridge where Bernal inspired so many fruitful new lines of work, and my school at Manchester. But I cannot forbear contemplating with considerable pride and complacency all the active centres where work of first-rate importance is now being done, and I have taken as the subject of my address a review of these centres. It would perhaps be logical to arrange my matter under subject headings—minerals, organic compounds, metal structures, and so forth, but I do not propose to adopt this plan. I see the development of X-ray analysis as due to a number of centres, inspired by original and brilliant leaders, and I wish to consider some of these centres in turn and describe their work. I wish I could deal with them all, but this would take too long, and I can only give a very brief and superficial review.

4. It is natural to speak of Bernal's work first because no one has done more than he has as an explorer and pioneer. Time and again, when reviewing some branch of X-ray analysis which is now very active, we have to acknowledge that the first critical experiment was due to his inspiration. Settlers have moved in to farm the land, but he has been the pioneer who pushed the frontier forward ; one may add that, like all true pioneers, he becomes impatient and restless when the new country is developed, and moves to fresh fields ! As I have worked in X-ray analysis from its start, I am perhaps as well placed as anyone to judge what his contributions have been, and remember the impressive novelty of lines of approach which we now all take for granted as well established and classical methods. In the early days we painstakingly examined X-ray diffracted beams one by one with an ionisation chamber. Highly accurate analyses are now made by the far more rapid method of recording all the beams on a photographic plate. The method itself was not new, but it was Bernal who showed us how to systematise and docket the observations and draw logical and far-reaching conclusions from them about the architecture of complex compounds. The paper by Bernal and Fowler on water will always be a classic, as showing how much information could be got from the diffuse X-ray haloes produced by a liquid. I well remember his first review of metal structures and the wide generalisations he made. It was he who first obtained a regular diffracted pattern from a protein crystal, a subject of which we are to hear more from Perutz this morning, and he advanced further to study the scattering by the very large scale regularities in virus preparations. These fields have now been far more intensively studied ; his work only gave an indication in each case of what might be discovered, but it made the first steps possible.

Another centre in London will be represented this morning by Mrs. Lonsdale, who started her investigation of diffuse X-ray scattering at the Royal Institution. The analysis of crystal structure is based on diffraction of X-rays by the regular pattern of the crystal. Each periodic variation in density due to the repeat of the pattern reflects a corresponding X-ray beam. However, any periodic variation of density produces the same effect, and consequently the thermal waves in a hot crystal diffract X-rays, as was first shown by Guinier and Preston. I can leave it to Mrs. Lonsdale to tell you about her development of this subject, and will merely say how interesting it is that X-ray analysis should find such an unexpected application, as a harmonic analyser of the elastic ripples running in all directions in a hot body. Mrs. Lonsdale was one of the first two women ever to be elected to Fellowship of the Royal Society. She was shortly followed by another X-ray crystallographer, Mrs. Hodgkin, and we may claim with pride that X-ray crystallography has indeed contributed to history by providing a field in which they established their reputations.

Mrs. Hodgkin is to tell us this morning about her work on penicillin, and no better example could be found of the art of crystal analysis. I would like to remind you of some characteristics of this art. The experimental work consists in recording, indexing and measuring a large number of spectra or diffracted beams of X-rays, each of which corresponds to a periodic element in the crystal pattern. The number of these measurements often rises into four figures. These periodicities must be accounted for by the arrangement of the atoms, and the more complex the crystal, the larger is the number of co-ordinates which are needed to define the positions of the atoms. The progress of crystal analysis can be measured by the increase in the number of co-ordinates or parameters which can be dealt with. In the first structures my father and I analysed in the early days, the atoms were at points of symmetry and there were no parameters to determine. An early triumph was the analysis of crystals with one parameter such as calcite and pyrites. But nowadays crystals

with anything up to one hundred parameters are confidently tackled, a task which would have seemed almost beyond the bounds of possibility to the early workers. The inherent difficulty of such work consists in its being very rarely possible to deduce the structure directly from the observations. On a strictly analytical basis, the observed diffractions might be caused by an infinity of structures since the relative phases of the periodicities do not affect the strengths of the diffracted beams, and the solution only becomes unique when we impose certain conditions, in general that the pattern-unit consists of a discrete number of atoms of known form. No way has as yet been found of arriving directly at a solution consistent with these conditions by a mathematical treatment, though attempts to do so have been made, and crystallographers have to fall back on a process of trial and error. In effect, one has to guess a likely structure, calculate how it would diffract, and compare with observation ; if there is no correspondence, a fresh guess has to be made. So in solving a crystal with one hundred parameters, one is trying to guess successfully all their values simultaneously.

The observations themselves are generally not difficult to make. Sometimes a crystal is very small, or unstable, sometimes it is difficult to get a perfect specimen. But on the whole the making of the observations is a matter of routine. The real work lies in their analysis. So in an X-ray laboratory one finds a deserted room full of apparatus in which the photographs are taking themselves, and a series of annexes in which absorbed workers are wrestling with masses of observations and calculations. I always find it an interesting contrast. Here on the one hand are a few photographs of some unknown structure. Hidden in the pattern of diffracted spots lies all the information required to establish the structure, if only one can find the ' open sesame ' which would reveal the treasure. The material is so simple, the analysis so very difficult.

How is it done ? The analyst has before him the separate bits of a jig-saw puzzle, each one of them being a periodic element in the structure, and he has to fit them together so that they build up a picture which makes sense, meaning by this a distribution of scattering matter corresponding to the atoms which he knows to be there. In making guesses at possible arrangements, he draws on a wealth of experience of the way atoms associate together in space, obtained from previous analyses. He pushes the atoms this way and that, remembering as he does so the many other alleys he has previously explored which have proved to be blind. It is, alas, a long time since I last analysed a structure personally, but I can well remember the intense concentration. One lived with the structure, I am tempted to say one ate, slept, and shaved with it. Finally, after six months or longer, and if one were fortunate, everything suddenly clicked into place. An arrangement was found which fitted so well to the most important observations that it was clear that one was on the right track at last. Once the general scheme is discovered, the final adjustments are relatively easy, and one more example is added to the growing list of known structures. Again there is a curious characteristic of this crystal work ; we can be sure of our results. Further refinement may be made later, but the evidence that our guess is right in the main is quite overwhelming and certain.

These analyses take a long time, and can only be made by the expert. What is the reward which lures him on to concentrate so intensely on establishing a picture of some twenty or thirty atoms arranged in a pattern ? There are so many structures to do, and so few people who can work them out, that it seems an endless task to examine them all. But it is not really so hopeless, because the successful analysis of one structure often leads to a quite new understanding of a whole range of forms of matter. The structure of diopside, for example, marked the turning-point in our understanding of the nature of all silicates ; the structures of one polyacid shows how they are all built up ; the structure of a few simple salts led Pauling to formulate the rules which determine the structure of inorganic compounds in general. It is all the more important that really key structures should be chosen for examination, as likely ventures in which it is justifiable to sink one's capital.

I have made this digression here because the nature of X-ray analysis is so well exemplified by Mrs. Hodgkin's work. Her success in analysing penicillin is a natural sequel to earlier triumphs, such as the solution of cholesteryl iodide which verified the nature of a typical sterol complex. She is a leading expert in the most difficult kind of pure crystal analysis, establishing the shape of very complex and unsymmetrical molecules. It is fair to claim, I think, that our country has almost a monopoly of this art in its highest form, and I would like to refer to a few other cases which to me are outstanding examples. One of these is Jeffrey's analysis of geranylamine hydrochloride. Some may wonder why a structure with so exotic a name was considered of high importance, but the point is that it has elements of isoprene linked together, and rubber is polymerised isoprene. This intense study of two joined links of a

rubber chain may well cast a flood of light on the general nature of rubber-like bodies. Another recent example is the solution of a sucrose compound by Beevers and Cochran. The sugars form very unsymmetrical molecules; in this case a sixfold and a fivefold ring are joined together and the bond lengths and bond angles have been determined. I always find an elegance in the method of attack on such complexes which is aesthetically satisfying. The solution seems so obviously right once it has been found, and explains so much.

Beevers is in charge of the Dewar Crystallographic Laboratory in Edinburgh, another centre where highly complex molecules are being analysed like the sucrose molecule mentioned above. His earlier work was largely on water of crystallisation and the structure of complex hydrates generally. At present J. H. Robertson, in his laboratory, is making an attack on the alkaloids. The structure of strychnine is still not known with complete certainty, although it has been studied so intensively by the organic chemists. The workers in the Dewar Laboratory have made considerable progress with compounds of strychnine and brucine; it will be a very real triumph if their exact configurations are determined by X-ray analysis.

5. In another side to the work on organic compounds the emphasis is upon the accurate determination of atomic positions. Robertson at Glasgow has been making a systematic examination of relatively simple molecules in which the chemist already knows the relative positions of all the atoms, his object being to translate such ' chemically known ' structures into terms of exact bond-lengths and valency angles, and correlate them with valency theory. He has determined the carbon-carbon distances in a number of molecules, showing that there are many intermediate stages between the standard single, double and treble bonds. He is now engaged in a three-dimensional analysis of naphthalene and anthracene, the two structures which were analysed by my father some twenty-five years ago and were the first organic compounds ever to be determined. He is examining long saturated CH_2 chains in a series of dicarboxylic acids and finding an alternation of long and short bonds. He is also examining long sulphur chains in polysulphides and polythionates.

Another centre where both new structures and bond lengths of known structures are being examined is Cox's laboratory in the Chemistry Department at Leeds. Professor Cox has kindly supplied me with a composite diagram (Fig. 1) which enables one to see the scope of his recent work at a glance. In diphenyl and the related compound where hydrogens are replaced by fluorine, the interest lies in the nature of the central bond. It is shorter than the 1·54 Å characteristic of a carbon-carbon single bond in diphenyl, and Cox is studying the effect of the fluorine atoms in an attempt to discover the nature of the bond. Nitronium perchlorate is a compound in which $(NO_2)^+$ plays the part of a positive ion, as had been deduced by Ingold on chemical evidence. The analysis of $K_2SO_3.2NO$ establishes the nature of the negative ion; chemists have speculated about the structure of this compound for the last hundred years. According to the classical stereochemistry of nitrogen, the N—N bond in dimethyl tetramine should be of the normal single type; it proves to be 1·26 Å in length instead of 1·40 Å which is characteristic of a single bond, and to be co-planar with other bonds to the nitrogen atom, so it has more of a double-bond character. The other figures show interesting heterocyclic compounds.

Powell at Oxford has an X-ray centre which collaborates closely with the chemists. One interesting line of work has been on complex intermolecular compounds, for instance that of iodoaniline with trinitrobenzene. A similar line of work has been developed in James's laboratory at Cape Town University. In Powell's compounds the two large molecules are of such a shape that they conveniently pack together in equal proportions. James has studied more complex cases, in which each type of molecule is stacked in rods, and the rods are packed side by side. The repeat distance may not be the same for each kind of rod, so that there is no simple ratio between the number of molecules of each kind, and very complex and beautiful X-ray diffraction effects are produced. Perhaps the most striking of Powell's recent analyses has been that of substances which he calls ' clathrates '. Quinol molecules link together to form two systems of inter-penetrating networks. Each is like a wire-netting structure in three dimensions, continuous in space but not bonded to the other though interwoven with it. There are large open spaces in the meshes, and gas molecules act as ' fillers ' to occupy these spaces and stiffen the two networks relatively to each other. It has long been a mystery how such molecules as SO_2 could be bound by quinol so firmly that the whole structure had to be destroyed before they could be released. They are now seen to be very loosely held chemically, but completely caged in physically.

We have at Cambridge a group working on organic chemical problems, in which Cochran is the leader. Pyrimidines and purines are being analysed, as primary building stones in the nucleic acids. This group works closely with Professor Todd and his chemists.

The investigations described in the last two paragraphs are essentially part of an enquiry into the physical basis of the chemical molecule, an attempt to understand its dynamics more completely by discovering the relative positions of its atoms. The examples I have given, to which many more could be added, come under the head of ' chemical crystallography '.

6. The forms of matter which come under the heading of ' minerals ' are an interesting group. The essential property of a mineral is stability ; in other words its atoms are arranged in such proportions and positions that a minimum of potential energy is attained lower than that of any alternative grouping. Hence arise both the limited numbers of minerals, and the very rigid

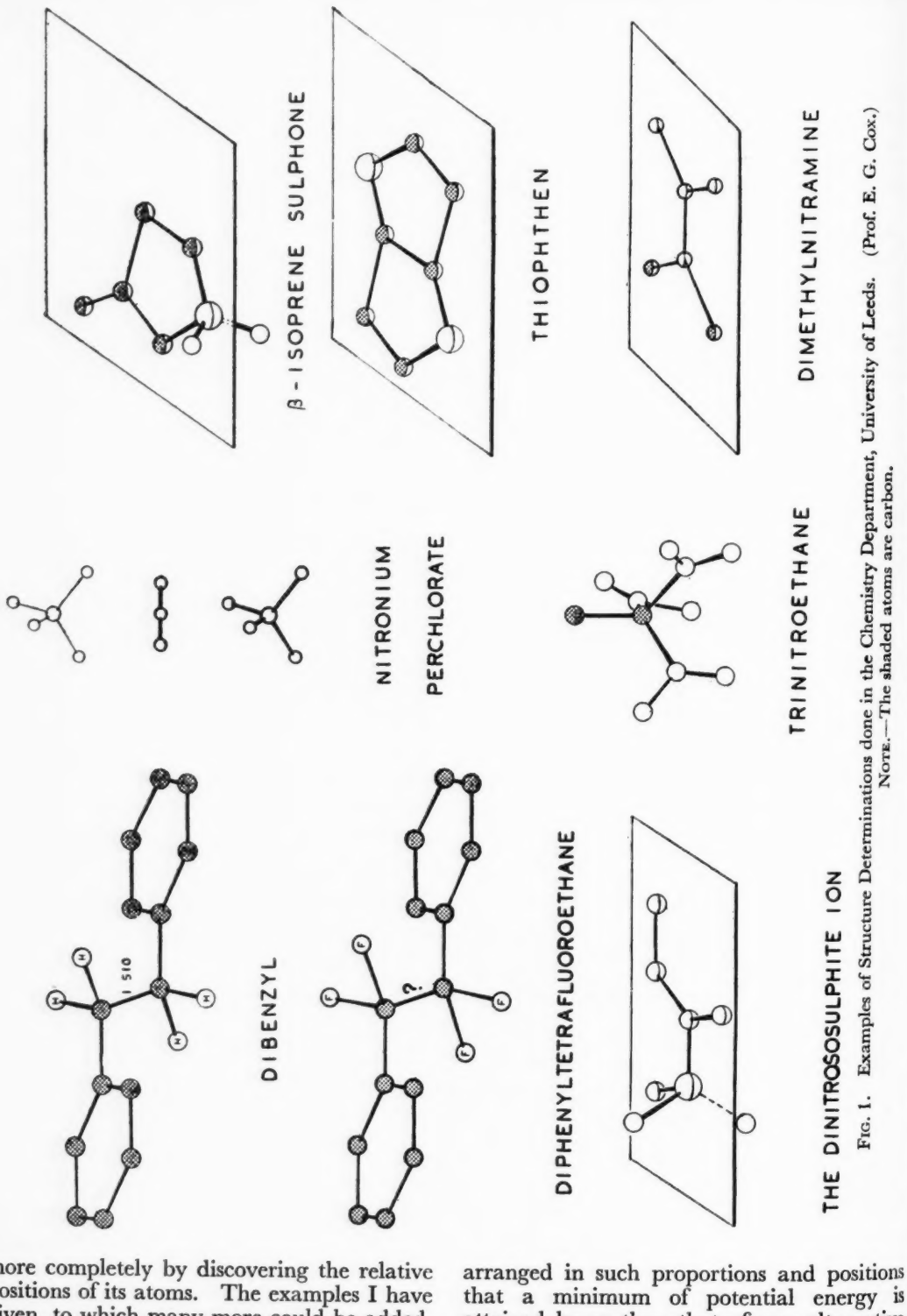

FIG. 1. Examples of Structure Determinations done in the Chemistry Department, University of Leeds. (Prof. E. G. Cox.)
NOTE.—The shaded atoms are carbon.

geometrical laws which their structures obey. The deducing of the structural relationships in the mineral kingdom, particularly those in the silicates, has been one of the triumphs of X-ray analysis. The broad outlines of the scheme are now clear, but there are several fascinating lines of work to pursue.

The work which is being carried out at the British Museum of Natural History by F. A. Bannister is an excellent example of the use of X-ray methods. Mineralogists have collected and named varieties from all parts of the globe. There is so much isomorphous replacement in minerals that composition is often an uncertain guide to the identity of a specimen. It is very interesting to note, now that we know more about internal structure, how right the mineralogists have been in allowing themselves to be guided by external form rather than composition in classifying their mineral species and families. But many minerals are in a microcrystalline state where external form is of no assistance. Bannister is carrying out a planned programme of mineral examination, which is leading to improved identification and classification. New minerals are being discovered which were previously unsuspected constituents of specimens, and minerals to which different names had been assigned are being shown to be of similar structure. Since X-rays readily tell us the number of atoms in each unit of pattern, formulae can be rewritten with far more certainty.

The felspars are the most important constituents of the earth's crust, and are outstanding in their importance to petrologists who study the history of rock formations. They vary in composition and symmetry, but their external form shows that they are closely related. W. H. Taylor first established their structure, showing that they are all based on the same characteristic pattern. Typical formulae are KAl_3SiO_8, $NaAl_3SiO_8$, $CaAl_2Si_2O_8$. The aluminium and silicon atoms form with the oxygens a continuous framework of tetrahedra, in the meshes of which the other ions are incorporated. But although the same structural type is common to them all, they are rich in variety and there are many fascinating differences of second order in their structures and properties. Minerals of the same composition may have different optical properties and even different symmetry, and these differences are related to the history and mode of formation of the rock in which they appear. Taylor is now trying to study these finer details. Why does a pure potash felspar appear sometimes to be monoclinic in symmetry, and sometimes triclinic? What is the cause of the irreversible change in optical properties which some specimens undergo on heating? How do the structures fit together in felspars which are alternate slices of potassium and sodium felspar? Finally, what is the structure of the intermediate forms between $NaAlSi_3O_8$ (albite) and $CaAl_2Si_2O_8$ (amorthite)? This last is a very intriguing problem. The series has always been regarded as a typical case of simple isomorphous substitution, but X-ray diffraction shows that it is really a very complex phenomenon. Extra diffraction spots show that larger-scale repeats are superimposed on the simple felspar pattern, in a way which depends on the proportions of sodium and calcium. The problem is interesting for its own sake as an example of X-ray optics, but also important because we wish to understand what conditions have produced these variations in the rocks.

Finally I must refer to the work on clay minerals which G. W. Brindley is doing at Leeds. Clays are composed of minute spangles of mineral, tiny sheets of mica-like structure which are often polar in their nature One face of the sheet is different to the other, they have ' bread ' and ' butter ' sides, and it is probably this polar nature which prevents their crystallising on a large scale owing to their tendency to curl and warp. These sheets form, as it were, the experimental benches on which the chemical operations in the soil are carried out. Nothing could be of more importance to soil chemistry than a knowledge of the structures of the clay minerals and their related species.

7. Passing now to the structure of metals, we may conveniently distinguish between two fields of investigation. On the one hand, there is what may be called ' metal chemistry ', the physical basis for the types of structure formed by metal atoms in various proportions ; on the other hand, there is the study of what may be called the ' physical geography ' of metallic aggregates. By this last is meant the size and orientation of the crystallites in a metal, their strains and structural distortions, incipient segregations into different phases such as take place in age-hardening, and exchanges of atomic position such as take place in the order-disorder change. The physical properties of a metal or alloy are much influenced by these characters. On both sides, X-ray analysis has made contributions of really vital importance.

I think it may be fairly claimed that alloy chemistry had no rational basis until structures were determined by X-rays. There is an interesting difference in character between a metallic compound and other kinds of chemical compound. One can, of course, find examples of all intermediate stages, but we are concerned here with broad generalisations. A typical metal compound is composed of markedly electropositive atoms. It

follows, as a consequence of the dynamics of such a structure, that wide variations in composition of any one alloy 'phase' are possible. In an extreme case, such as copper and gold, all proportions can unite to form a single structure. This is in complete antithesis to the relationship between sodium and chlorine, for example, when we find pure sodium, pure chlorine, or sodium chloride with the exact stoichiometrical relationship represented by the formula NaCl. To call the former a case of solid solution and the latter a true chemical compound takes us no further in explaining the physical basis of the difference. We may perhaps express the nature of an alloy by saying that different possible arrangements of the metal atoms, or different phases, are separated by fine second-order differences in their potential energy so that very little tips the structure in one direction or another. A compound such as NaCl is at the bottom of a deep narrow pit of potential energy, and the slightest variation in composition increases the energy greatly. An alloy is at the lowest point of a very shallow bowl with many alternative bowls open to it whose bottoms are nearly at the same level. What is equally important is that metal atoms are very mobile and readily exchange positions, and as a consequence these finer differences have an opportunity to be effective. Hence arises the rich variety of changes that can take place in an alloy system, and the great influence upon it of its thermal or other history.

It would take too long to tell the whole story. I will just remind you of the early work of Westgren on alloy phases, the realisation by Hume-Rothery and by Westgren that similar free-electron atom ratios often produced similar phases, the work of Bradley on the structures of complex intermetallic compounds which provided so many examples of the Hume-Rothery rule in binary, ternary and quaternary phase systems, and the theoretical work of Jones on the explanation of the Hume-Rothery rule by the filling of Brillouin zones.

Raynor at Birmingham has as his general objective an understanding of equilibrium relationships and the occurrence and structure of intermediate phases in alloys, so that a comprehensive theory of alloys may be developed, permitting quantitative prediction of the results of mixing metals together. He is concentrating mainly on compounds of aluminium with the transition metals. Fig. 2 will serve as an indication of the type of prediction which may be made.

All this work is still on a semi-empirical basis. It is clear that the Hume-Rothery rule corresponds to one highly important factor which determines which phase a given composition of metal atoms will adopt, but also that it is not the only factor. For instance, relative sizes of the atoms play their part as well as the electron-atom ratio. We need to know the structures of far more intermetallic compounds, and these are often very complex and the analysis is lengthy. Mrs. Douglas at Cambridge is collaborating with Raynor, doing the structure analyses of the phase systems he is surveying. If we are examining an inorganic or organic compound, we can safely assume that neighbouring atoms have certain well-established relative configurations and conform to rules with which we are familiar. So far we have no such rules for intermetallic compounds and each structure presents quite a novel problem. We are only at the beginning of an understanding of metal chemistry.

Investigations of alloy phases are concerned with the arrangement of the atoms in the unit cells of a regular crystalline pattern. But the perfect regularity is an ideal state which is only attained under special conditions, and I pass on to describe the application of X-ray analysis to study the many interesting and important types of departure from the ideal lattice.

We know of many cases where two metals are completely miscible over a wide range of composition at higher temperatures, with atoms of either kind occupying the sites of the same lattice in a random manner, but where interesting changes in structure take place when the temperature is lowered. Two broad classes may be distinguished; there may be a tendency for like atoms to get as far apart as possible, or to associate together. The former state of affairs leads to the well-known order-disorder change, first examined by Borelius and then by Bradley and Sykes using X-ray analysis. A very imposing literature now exists devoted to this phenomenon alone. Order-disorder is only observed when the composition is near a simple one such as AB or A_3B; the alloy Cu_3Au is typical and has been intensively studied. At high temperatures copper and gold atoms replace each other at random on a face-centred cubic lattice, at lower temperatures the gold atoms segregate to the cube corners, leaving the face-centres to the copper atoms. In this way the gold atoms find positions as far apart as the composition permits, and a larger-scale regularity is superimposed on the simpler lattice. The thermodynamics of the change is of such interest as to have attracted theoretical physicists of the order of Bethe and Peierls, amongst many others. With different rates of cooling, a series of intermediate states is produced. The ordered states grow from nuclei which are out of step with each other, different points of the lattice being

chosen as cube corners for the gold atoms. The more rapid the cooling, the smaller are the domains in which the same scheme of order is preserved. Lipson at Manchester has been investigating these stages more deeply by obtaining diffraction effects from single crystals of Cu_3Au (Sykes had previously used the powder method to establish their final consequence of such a process if it proceeds to equilibrium is of course two separate phases, one of which is rich in atoms A and the other in atoms B. Again, however, a set of intermediate states is formed if the temperature is lowered too rapidly. The atoms remain in a single continuous crystal lattice, but they segregate so that parts of the lattice

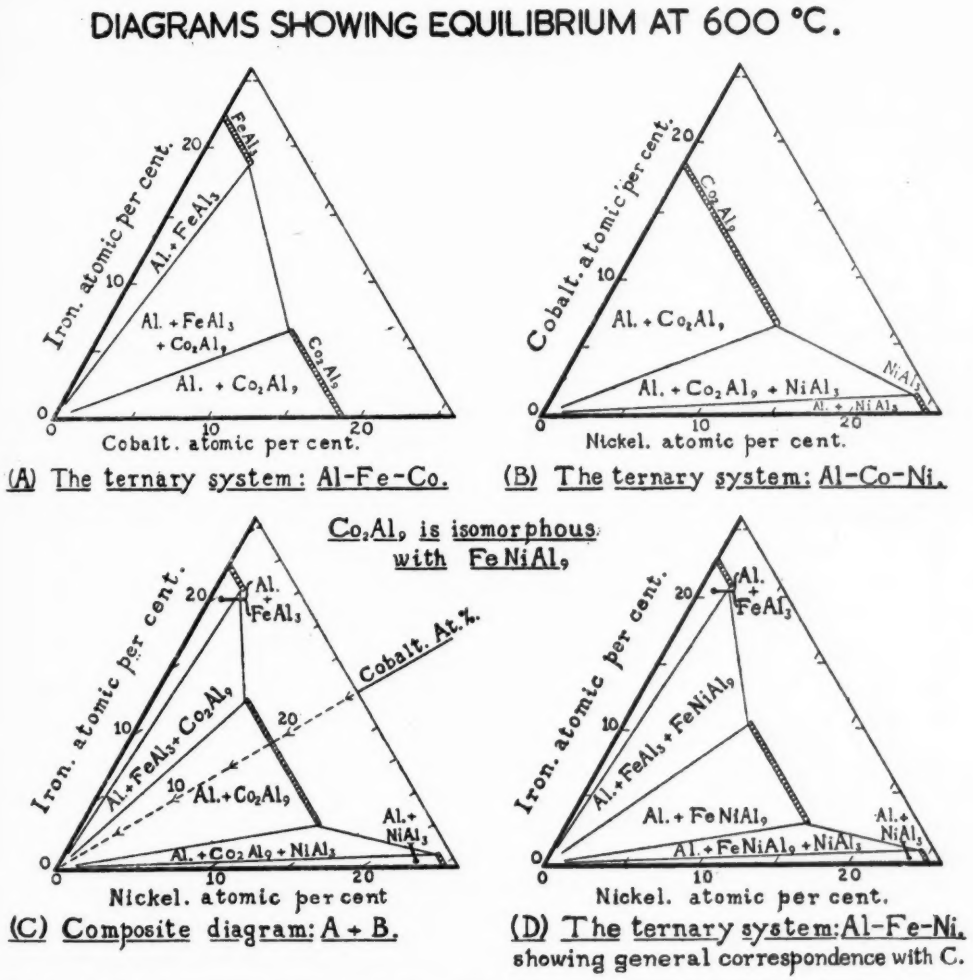

FIG. 2.—A and B represent respectively the aluminium-rich isothermals at 600° C. for the systems aluminium-iron-cobalt and aluminium-cobalt-nickel. In C, these two diagrams have been re-drawn in triangles with angles of 90°, 60° and 30°, and placed together with the aluminium cobalt axis common. The composite diagram is closely similar to that established experimentally for the aluminium-iron-nickel alloys (D); agreement is quantitative, except that Co_2Al_9 is less sensitive to a reduction in the electron-atom ratio than the less stable isomorphous $FeNiAl_9$ phase. These relationships are due to the fact that, electronically, Fe+Ni=2Co. (Dr. G. V. Raynor.)

existence), and he has found some very interesting features of the way the different nuclei dovetail into each other. The order-disorder transformation in metals has proved to be very interesting indeed, because it is a simple example of a general phenomenon, lends itself readily to theoretical treatment, and gives information about the exchanges of position of atoms.

The converse phenomenon is to be observed when like atoms tend to come together. The are rich in A and other parts rich in B. The lattice is consequently modulated because the lattice constants are slightly different in the A-rich and B-rich regions. The crystal planes are corrugated in a more or less regular manner. Such modulations produce sidebands to the X-ray diffraction lines in a powder photograph, and the nature of the modulation can be deduced from the sidebands.

These metastable states are of immense

importance to technology, because they confer certain physical properties on the metal in which they are formed. The modulations of structure set up intense local strains. Their X-ray diffraction effects were first studied in permanent magnet alloys by Bradley. Age-hardening alloys, studied by Guinier and Preston, afford another example. The intensely hard martensitic structure in steel is caused by the dissolved carbon atoms taking up preferred sites, so modifying an initially cubic crystal by making it a mosaic of slightly tetragonal regions which have their C axes in different directions, but still all form part of a single modulated lattice.

The literature which describes the X-ray study of the effect of plastic distortion upon metals would form the material for a book. Preferred orientation, crystal break-down, and the locked-up stresses in the crystallites have been studied. Some very interesting work on this last subject has been done recently by Greenough at Cambridge and at Farnborough, by Lipson, and by Brindley.

These examples only indicate the kind of work which is going on, but they will serve to show the importance of X-ray analysis in metallurgy.

8. The last field I shall consider is represented by the paper which Perutz is giving to us in this session. X-ray analysis is being extended to more and more complex substances; can we establish the structure of the molecules of which living matter is made? Protein molecules contain thousands of atoms. Each kind of protein appears to consist of identical molecules, for they crystallise and give X-ray diffraction patterns which indicate a highly perfect structure. The photographs which Perutz and others have taken are like a message in code which we cannot yet decipher. The information is there, if only we can discover the key. It would be a wonderful climax to the progressive advance of X-ray analysis if protein structure were solved by its aid. Perutz will describe how far we have got at present. The full analysis seems an almost impossible feat, but the analysis of sugar or of penicillin would have seemed equally impossible in the early days of X-ray analysis.

The proteins are being attacked from another side by Astbury and his school. Such substances as hair and wool, horn nail or spine, are a more or less irregular mass of the same chains which are so perfectly arranged in the protein molecule; they are a kind of oakum of protein strands. In some respects they are more simple than the large protein molecules, because one is dealing with the fragments of a feature common to all such structures; in another sense their study is far more complicated because their arrangement is so imperfect. They give correspondingly diffuse and limited X-ray diffraction effects, and Astbury has been engaged in extracting the maximum amount of reliable evidence from these very unsatisfactory witnesses. If the way in which polypeptide chains are folded in the protein could be established, a big advance would have been made, and Astbury's work has done much to help with this problem.

9. I should have liked to have added an account of the applications of X-ray analysis in some of our great industrial laboratories. Bunn of I.C.I. has made contributions to fundamental research as well as to the elucidation of technical chemical processes; for instance he collaborated with Mrs. Hodgkin in the analysis of penicillin. The late A. H. Jay, working in the research laboratory of United Steels, made a name for himself as an expert on refractories. The General Electric Company, Jessops, Firth-Brown, and many other firms have flourishing X-ray centres. The industrial laboratories are as well represented as are the university centres at the annual meetings of the X-ray Analysis Group of the Institute of Physics. But it would lead me too far afield if I were to begin to do justice to the importance of the contributions from so many centres, and I have had perforce to content myself with a survey of the work going on in our university laboratories.

Laue discovered X-ray diffraction only a generation ago. X-ray analysis has now come to be of such importance that the formation of an International Union of Crystallography has been approved by the Council of International Unions this year. It has indeed attained its majority, and I feel deeply moved when, on such an occasion as this, I review the tree which has grown from the seed of Laue's original discovery and the early attempts by my father and myself in 1912 to discover the arrangement of atoms in crystals.

SECTION B.—CHEMISTRY

SPECIALISATION AND CULTURE IN CHEMISTRY

ADDRESS BY

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PRESIDENT OF THE SECTION

PARACELSUS, referring to our alchemical forerunners of the early sixteenth century, wrote: 'They are not given to idleness, nor go in a proud habit . . . but they diligently follow their labours, sweating whole days and nights by their fiery furnaces. They do not go out promenading, but take delight in their laboratory . . . They put their fingers amongst the coals, the lute, and the dung, not into golden rings . . . They reject such vanities, and delight to labour in the fire and learn the steps of alchemy.'

In the middle of the next century, to the seeker after new chemical knowledge, Glauber said: 'It is easier to add to things already found out, than to become the first Author of new inventions . . . He that seeks shall find. Wherefore rise from your soft Pillows, and with smutted Hands touch black Coals, and accurately give heed to the institutions of Art. For with Idleness, Eating, Drinking, and playing on Musick, you shall never approach to great Mysteries.'

Even in those early days chemistry was an exacting mistress, especially to the original investigator. Yet in that period and throughout the eighteenth century the accumulation of chemical knowledge proceeded very slowly. The tempo increased rapidly in the nineteenth century, until now, in the twentieth century, research in chemistry, as in science generally, has moved forward in a kind of geometrical progression. As a consequence, teachers, students and research workers alike have to struggle under a rapidly increasing burden of new knowledge. How can the teacher present the vast new stores of information, theories and ideas? How can the student and research worker assimilate them? How can teacher, student or investigator gain a broad view of his own branch of science, to say nothing of science as a whole? Such queries point in turn to the fundamental problem: how is the chemist (or, in general, the man of science—and much of what I am about to say has this wider application) going to acquire a proper education leading to a cultured outlook and fitting him to take his place in the world of men and affairs?

A consideration of the difficulties inherent in these various questions soon discloses a common factor. That common factor is specialisation. Most of us will agree that the phenomenal advances in science during the present century—made since many of us were at school—have led to an ever-increasing degree of specialisation in the teaching and practice of its various branches, including chemistry, and that in some respects the consequences are bad. It is true that the microscope has increased in power; but the field of vision has narrowed. Specialisation cannot be avoided at this stage in the development of science; and although no complete solution of the accompanying problems may be possible, we ought at least to take what steps we can to combat the narrowing outlook which now threatens to affect science students at all levels, and we ought particularly to bear in mind their social, cultural and spiritual needs.

We may well begin by taking a historic glance at the growth of this specialisation in chemistry. Although chemistry has always been an exacting mistress since the days of the alchemical adepts and 'puffers,' there was no undue specialisation, leading to a conflict between technical proficiency and general culture, until comparatively recent times. Writing of the Dutch chemist, Boerhaave, in 1739, Dr. Samuel Johnson remarked that 'when he had attained one science [he] attempted another: he added physic to divinity, chemistry to the mathematicks, and anatomy to botany.' He held simultaneously the three chairs of medicine, botany and chemistry in the University of Leyden; and Ferguson described him as 'the most distinguished teacher of his time, and a man of immense and varied learning in languages, philosophy, theology, mathematics, botany, chemistry, anatomy and medicine.'

In 1756 we find Joseph Black and one of his colleagues at Glasgow exchanging their chairs of anatomy and medicine, the latter of which Black forsook for the chair of chemistry and physic at Edinburgh ten years later, owing to Cullen's migration from that chair to a medical one. The restricted range of the various branches of science and medicine made possible this species of 'academic musical chairs' in the eighteenth century.

At Cambridge in 1764, Richard Watson being, as he said, 'tired with mathematics and natural philosophy,' got himself elected to the chair of chemistry, so as 'to try his strength in a new pursuit.' He confessed that he 'had never read a syllable on the subject, nor seen a single experiment'; so he obtained 'an operator' from Paris, devoted fourteen months' study to the subject, and then embarked upon a course of lectures and practical demonstrations that gained great popularity. His election to the Royal Society followed in 1769, and two years later he succeeded to the regius chair of divinity, admitting that he 'knew as much of divinity as could reasonably be expected of a man whose course of studies had been directed to, and whose time had been occupied in, other pursuits.' In 1782 he became Bishop of Llandaff; but it stands to his credit that his love of chemistry remained, for it was in this period that he published his well-known work, *Chemical Essays*, in five volumes.

This attitude towards chemistry, so liberal and so spacious, lasted into the nineteenth century. In the 1840's at Oxford, the versatile Charles Daubeny held simultaneously the three chairs of chemistry, botany and rural economy, and wrote not only on the atomic theory, but also upon a diversity of other subjects, such as volcanoes, manures, and the sexuality of plants. At the same time, Liebig, the foremost chemist of the day, although working assiduously 'from break of day till nightfall' in his crowded laboratory at Giessen, was able to lead a calm and quiet existence reflected in his remark to Faraday: 'We take walks in our beautiful green woods and in the evening drink tea at the neighbouring old castles. This is our recreation.'

The great change setting in towards the end of the century is evident from some words of Richard Semon, the naturalist, who wrote in 1899 that science threatened 'to produce an unlimited number of specialists, each of whom is blind to everything but the narrow sphere of his chosen department.' Yet, in the early years of the present century it was still possible for a young research worker to keep abreast of the current advances in the whole field of chemistry. In those days (*et ego in Arcadia*) an enthusiastic chemist could read through an issue of a standard chemical research periodical from cover to cover, with as much zest and enjoyment as he would derive from the latest novel of Conan Doyle or Stanley Weyman. Nowadays that is unimaginable.

In those days, too, a chemistry student was trained to become an all-round practitioner of his art. If he went on to research he had to be self-reliant; he was, indeed, a self-contained unit. When he synthesised a new organic substance he carried out the combustions and Carius determinations with his own hands. If the results did not agree he repeated his work time and again until they did. Moreover he had to exercise care and economy. If he cracked his combustion tube he had to buy another. In most research laboratories also, he had to pay for the special chemicals required in his research work. The few research scholarships then available acted as further inducements to care and frugality.

Growing specialisation and an expanding endowment of research in the last few decades have altered all that. The vision of the student and research worker has narrowed. So has the range of accomplishment in the laboratory. So has the need for economic working. We have entered into an age of team-work. It must be admitted freely that team-work has accomplished great tasks that could hardly have been achieved in any other way. Chemical science has been aided nobly by such work; but the individual worker is liable to sacrifice a great deal in the process. Team-work, however important, should be applied with restraint. Instead of breeding the man of broad vision and all-round accomplishment, we now stand in danger of producing men who will go through life in chemical blinkers: one may become a catalytic hydrogenator; another may relapse into a permanganate-oxidiser; recently also the plaintive question was overheard: 'Can a physical chemist be interested in real chemistry?'

In brief, the outstanding characteristic of the pioneers of chemistry was a rich multiformity and individuality, flowing from the diverse nature of their education and training, often obtained only with great difficulty. 'Doctor,' exclaimed Berzelius reprovingly to Wöhler, who was carrying out quantitative analytical work beside him in the Stockholm laboratory, 'das war geschwind aber schlecht [that was fast but faulty]!' In such a way Wöhler learnt from the great master to become a dependable analyst, trusting to his own hands and not sacrificing accuracy to speed. The replacement of multiformity by uniformity and of individuality by regimentation is bound to lead to a loss of much of

that zest and sparkle, and of that pride in one's own handiwork, which stood out so strongly in the work of such early craftsmen of chemistry as Berzelius and Bunsen.

The mental effect of an unrelieved absorption in a specialised field of science has been vividly described by Charles Darwin in his autobiographical notes entitled 'Recollections of the Development of my Mind and Character.' 'Up to the age of thirty, or beyond it,' he wrote, 'poetry of many kinds, such as the works of Milton, Gray, Byron, Wordsworth, Coleridge, and Shelley, gave me great pleasure, and even as a schoolboy I took intense delight in Shakespeare, especially in the historical plays. I have also said that formerly pictures gave me considerable, and music very great delight. But now for many years I cannot endure to read a line of poetry: I have lately tried to read Shakespeare, and found it so intolerably dull that it nauseated me. I have also almost lost my taste for pictures or music . . .

'I retain some taste for fine scenery, but it does not cause me the exquisite delight which it formerly did. On the other hand, novels which are works of the imagination, though not of a very high order, have been for years a wonderful relief and pleasure to me, and I often bless all novelists. A surprising number have been read aloud to me, and I like all if moderately good, and if they do not end unhappily—against which a law ought to be passed. A novel, according to my taste, does not come into the first class unless it contains some person whom one can thoroughly love, and if a pretty woman all the better.

'This curious and lamentable loss of the higher aesthetic tastes is all the odder, as books on history, biographies, and travels (independently of any scientific facts which they may contain), and essays on all sorts of subjects interest me as much as ever they did. My mind seems to have become a kind of machine for grinding general laws out of large collections of facts, but why this should have caused the atrophy of that part of the brain alone, on which the higher tastes depend, I cannot conceive . . . The loss of these tastes is a loss of happiness, and may possibly be injurious to the intellect, and more probably to the moral character, by enfeebling the emotional part of our nature.'

This growth of specialisation has led to many criticisms of the effects upon the human subject of a scientific training followed by a career in science. It is often said that students graduate in science with a good technical training; but to the neglect of their general education and culture. Other critics go further. Possibly some of them have attended a number of strictly impersonal lectures on science, from which they have deduced that the man of science is of necessity cold, formal and aloof; narrow in outlook; insensible to the finer human emotions; incapable of expressing himself in the common tongue; devoid of humour and humanism; and a stranger to the humanities. A recent writer characterises 'the fragmentation of knowledge into unco-ordinated and increasingly unintelligible specialities' as 'the chief evil of our day . . . in a world of the contented ignorance of the most learned in relation to every field of study but their own.' He adds that 'the specialists . . . seem for the most part apparently unconscious of the very need of the synthesis which they have left the "amateur" to attempt.' Another critic, the chancellor of an American university, is reported to have said last May that the primary faults in American education were over-stressing of professional training and over-specialisation. Many American professors were able to deliver speeches in their particular subjects, but could hardly talk of more than the weather or politics in private conversations.

Some of these statements call for careful consideration from men of science; some are clearly intemperate; others take us into a region of grotesque misrepresentation. In a broadcast earlier this year, for example, a speaker likened the man of science to a bee: as marvellously efficient in his specialised avocation as is the bee in extracting honey from the flower and conveying it to the hive; but take him from his laboratory into the outer world, continued this egregious pronouncement, and he becomes as helpless as a bewildered bee transferred from the hive to a window-pane!

Dismissing such irresponsible and mischievous statements for what they are worth, it will not be seriously contested that the intense specialisation which is an inevitable consequence of the expansion of science is bound up with serious handicaps. To what extent may these be overcome, or at least ameliorated?

In trying to answer this very hard question we must begin our analysis of the position by looking at the incipient scientist in his passage through the schools. It is here that we view his education in its broadest aspect. Indeed, it is mainly at this stage that he is able to undertake an organised and continuous study of non-scientific subjects—which, for the sake of convenience, we may perhaps call arts subjects. It is in the schools, helped in the ideal case by home influences, that the firm foundations of these wider interests must be laid: if they are not laid at this stage they cannot be built upon later. Now the question of the education of the man of science

in the schools, and to some extent also in the universities, was debated very fully and eloquently by a number of eminent authorities at the Dundee meeting of the British Association last September ; so that it is unnecessary in this place to do more than comment upon some of the outstanding features, especially as they affect chemistry.

There should be no sense of antagonism between arts and science, either in the schools or out of them. These studies are complementary. Any form of modern education should be made up of a proper blend of each. It does not fall within my province to discuss the way in which the elements of science should be taught to non-scientists ; but the subject is one of paramount importance. As to what subjects should be included in the school curriculum of the future scientist, no hard and fast rule can be laid down, beyond saying that any strong interest of an individual pupil should be encouraged. In the words of Dr. Eric James : ' The character of a scientist's general education will depend far more on *what* the outside subjects are, and how they are taught than on their number.'

A primary requisite is that in the schools the future scientist should learn to express his thoughts in clear and simple English ; so that in his later life he may conform to the ideal that Defoe had in mind when he wrote : ' If any man were to ask me what I would suppose to be a perfect style of language, I would answer, that in which a man speaking to five hundred people, of all common and various capacities, idiots or lunatics excepted, should be understood by them all, and in the same sense which the speaker intended to be understood.' Such a command of English comes only gradually as a result of application to the writings of the masters, not forgetting the Bible, and of long-continued practice in writing and speaking. It is helped by the study of another language. Here, Latin has its special claims ; but the mastery of a modern language is to be commended, in that it may well bring in its train a living contact with a new culture.

Literature, history, art, music and the drama, besides their aesthetic appeal, have a direct human interest of particular value to the chemist, who at a later stage in his career must perforce spend most of his time in the laboratory or immersed in the vast impersonal literature of his science. A lively interest in subjects like these, gained in early life in the home or school and nurtured thereafter, would do much to solve some of the problems of specialisation in chemistry. But such interests must be fostered and not allowed to die. I have already referred to Darwin's delight, as a youngish man, in the poetry of Wordsworth and Coleridge. Earlier still, Milton's ' Paradise Lost ' had been his chief favourite, and in his excursions during the voyage of the *Beagle*, when he could take only a single volume, he always chose Milton. ' If I had to live my life again,' he wrote, much later, ' I would have made a rule to read some poetry and listen to some music at least once every week ; for perhaps the parts of my brain now atrophied would thus have been kept active through use.'

As regards the teaching of chemistry itself in schools, the method of teaching is possibly even more important than the amount taught. Habits of systematic work, clear thinking, and power to concentrate ought to be cultivated and established as a result of such teaching. Also the importance of expressing oneself clearly, accurately, and in simple straightforward language should be emphasised continually. A grasp of the fundamental principles of chemistry, gained at school, is invaluable to the student entering a college or university. These fundamentals, calling for a binocular qualitative and quantitative view, are not grasped easily by the average pupil. In the words of Joseph Black : ' That difficulty at first, and seeming want of Success, has its foundation in the nature and constitution of the human mind, which is more or less slow in the apprehension of Ideas and things, and requires a repetition of them to fix them in the memory.'

Such a thorough grounding in essentials, calling for understanding rather than memorising, does not need highly specialised teaching in the schools. Specialisation should indeed be avoided at this stage : it will descend upon the student soon enough in the college or university. We are bound to recognise however that in many instances the prevailing system of entrance scholarships and admission tests to universities has given rise to an undue specialisation in school science teaching. None of those concerned seems willing to accept responsibility for this state of affairs. A colloquial illustration may be apposite at this point.

Some years ago, being interested in the matter, I asked a professor of chemistry in a celebrated English university why the university insisted upon such high specialisation in chemistry in the entrance scholarship papers, pointing out to him certain specific questions in organic chemistry that might well have found a place in a Pass B.Sc. degree paper. ' Please don't blame us,' he said ; ' it is the colleges that are responsible. In the university Chemistry Department we are opposed to such specialisation at school. We prefer less chemistry and a greater facility in English and mathematics than is usually shown by such pupils. Some of them cannot even

write a passable letter.' I went straightway up the street to a college examiner and put the same question to him. 'My dear fellow,' he said; 'please don't blame us. Since the schools take their pupils so far, they would be disappointed if we set any other type of paper.' A few days later I retailed this answer to a chemistry teacher in one of the English public schools: he refuted it indignantly, saying that he was the last person who wished to turn his chemistry pupils into specialists, but that he had no option if they were to be in the running for entrance scholarships. Now if the three views obtained in this informal way are representative, it seems that here a vicious circle is waiting to be broken. Once the pace has been set, it becomes traditional and goes on from strength to strength, especially in the hands of the young and inexperienced examiner who is still thinking in terms of his own recent Honours examinations. I am convinced from an experience of many years that it is quite possible to appraise the relative merits of entrant candidates by means of searching questions on the basic principles of chemistry. Moreover such a paper is much fairer than a 'lucky dip,' containing random questions on advanced topics which a candidate may, or may not, have had the good fortune to 'spot.' An entrance test should not be made into a lottery.

We now pass from the school to the college or university. Here, considering the case of a competent student who wishes ultimately to specialise fully in chemistry, we shall probably agree that it would be well for him to devote four years to a course of study leading to an Honours degree in chemistry, followed by two or three years of research work in a special branch of this subject. Chemistry has become so mathematical, and also so physical, that the young chemist will do well to take the study of mathematics and physics as far as he can. He should also try to gain a knowledge of some branch of biology, otherwise his view of science and of nature will be unduly restricted. All these commitments leave him with little, if any, time to give to formal non-scientific studies, especially as he will need to devote some attention to gaining a reading knowledge of French and German. The maintenance of an open and lively mind is left largely, or entirely, to his own initiative. It is now that the social contacts with his fellows and personal acquaintance with a number of his teachers become so important. At this stage in his career the student in residence claims a great advantage over the 'travelling' student, to whom his college or university may mean little more than a seat in a lecture-room and a bench in a laboratory.

The way of teaching chemistry in the university is a matter of the first importance. If the teaching resolve itself mainly into a presentation of an endless series of massed facts and technical detail it is bound to favour the development of a one-track mind. It is such canalisation that leads the student to erect a barrier between chemistry and biology, between organic chemistry and physical chemistry, and even between first-year and second-year chemistry. Each notebook becomes to him a water-tight compartment filled with segregated collections of facts. It is true that numerous facts and details have to be presented to students of chemistry; but they should be arranged in an ordered sequence leading to a discernible goal. In examining the leaf we must not overlook the tree, and in studying the tree we must not neglect its ecology.

Although his chemical studies must deepen rather than broaden as the student passes through his Honours course into research work, he should always be encouraged to realise that chemistry embraces an ample field in space, also that it is widely dispersed in time. There is a chemical geography; there is also a chemical history: and these offer him avenues leading to a wider horizon. Let me interpose an illustration from the realm of everyday geography and history:

Many years ago, one of my friends at school and college, an electrical engineer, obtained his first appointment, at Newcastle-on-Tyne. 'In the midst of smoke and clatter,' he wrote to me at the time, 'I thought of the hedgerows and orchards of Somerset, and was "sick at heart." After a while I came across a map of the country round about. Whenever you settle in an unknown district be sure you buy a map. R. L. S. says truly, "Maps, of all books, are the least wearisome to read and the richest in matter." I then discovered that I was living in reach of a country overflowing with history and romance: battlefields and mountains, camps, castles, rivers, lakes and sea, were yonder, away beyond the horizon of roofs and chimneypots. I explored the great Roman Wall nearly from sea to sea; climbed great hills and wandered along the Tyne, from its source away in the Pennines to its mouth in the North Sea.' 'With what relish,' he added, 'can one now read Sir Walter Scott and revel in the Border ballads!'

So let us now follow R. L. Stevenson and open out our chemical maps. We shall find, in the first place, that chemical geography links the student of chemistry with economics, with industry, and even brings him to appreciate some of the fundamental causes of international rivalry and strife. With an eye upon this aspect of the subject, he will

begin to realise the importance of the situation of high-level water and coal, of the mineral oilfields, of the great vegetable oil-belt of the tropics, and of the areas of the world producing rubber, copra, essential oils, tin, asbestos, and many other commodities having a combined chemical, economic and industrial interest. A student brought up in such an atmosphere will cease to associate the chief use of linseed oil with cricket; and he will know something about the scale of production and the economic and industrial significance of substances like calcium carbide, sugar and alcohol. Moreover, if he proceed, for example, to research work on the chemistry of essential oils he will be sure to gain inspiration from the botanico-chemical investigations of men like R. T. Baker and H. G. Smith, who took a whole continent for their stage in tracing the phyto-chemical distribution and evolutionary development of that great and noble genus *Eucalyptus*, in Australia.

This reference reminds me that some years ago the Chemical Society of a certain English university invited me to lecture to the members. I sent to the officials of the Society as a title, 'The Chemistry of the Australian Flora.' They asked me to change this to 'Some Aspects of Recent Terpene Research,' on the ground that the first title had no 'examination value.' I declined to alter my title, pointing out politely that no coaching fee had been mentioned; and so the matter dropped. Soon afterwards the Botanical Society of the same university asked me for a lecture. I sent them the same title. They accepted, and I was gratified to find in the audience a large number of chemistry students who took an animated part in the ensuing discussion. The officials of the first society had clearly underrated the intelligence of their members. My experience has been that students are always responsive to broad treatments of suitable themes and to any effort to make science its own instrument of culture. The intelligent student has the latent interest and curiosity, and it rests with his teachers to develop such qualities.

It is when one attempts to humanise chemistry by writing books which depart from a traditional orthodoxy that one steps forth into the full force of the gale arising from a sudden release of segregated thought. As a very simple example, one may be taken to task for beginning a text-book of *organic* chemistry with a short discussion of the *general* historical development of chemistry; presumably also for mentioning Scheele's work in inorganic and organic chemistry on the same page! Of such apostles of a cold chemical rigidity, some of our outside critics might well be tempted to say: 'Chill *Chemistry* repress'd their noble rage, And froze the genial current of the soul.'

I have mentioned historical chemistry, and it is when we begin to contemplate chemistry-in-time that we realise more fully how chemistry itself may become a cultural and humanistic instrument of high value—whether we encounter this point of view in an organic text-book or in a work clearly labelled 'historical chemistry.' A long time ago, in 1871, Clerk-Maxwell wrote: 'In Science, it is when we take some interest in the great discoverers and their lives that it becomes endurable, and only when we begin to trace the development of ideas that it becomes fascinating.' By presenting chemistry merely as a regimented system of facts, laws, and theories we sacrifice to a large extent its educative value and abrogate its cultural potentialities. It is easy, for example, to explain the nature and relationships of isomerism in a cut-and-dried manner; but the phenomena acquire a new and vivid interest when related to the boy Liebig standing in the market-place at Darmstadt and watching a pedlar charging toy crackers with silver fulminate; to the almost simultaneous discovery by Wöhler at Stockholm and Liebig in Paris of the isomerism of fulminic and cyanic acids; to the ensuing lifelong friendship between these two paladins of chemistry; to the dramatic scene between Biot and Pasteur at the polarimeter, heralding the birth of stereochemistry; to Kekulé's visions of gambolling atoms and the snake biting its tail; and to the coincidence in time of the wider ideas upon which Le Bel and van 't Hoff based the fundamental theory of spatial chemistry.

Chemistry is indeed the most romantic of all the branches of science, and in its variegated history, stretching back through unnumbered generations of alchemists into an indefinite past, chemists have a richly humanistic heritage. In the words of Emil Fischer: 'Science is not an abstraction; but as a product of human endeavour it is inseparably bound up with the personalities and fortunes of those who dedicate themselves to it.'

Historical chemistry is linked in turn with philosophy, with literature, with art, and even with music—as the St. Andrews University Choir once demonstrated at the Royal Institution. This great heritage must not be neglected in the teaching of chemistry, especially in the more advanced stages, when the student has mastered the elements of the science and is able to take an intelligent interest in the problems that puzzled our chemical forebears. Although I think that school science courses should have a historical

background, dealing particularly with the human element, I do not favour the introduction of any *ad hoc* course of historical science into school teaching ; but some of the fundamental features of historical science ought to find a place in the general history course, and that for all kinds of pupils. As I wrote in 1926, it is at the university, later in his studies, that ' the student, having grasped the fundamental principles of . . . chemistry, should now be sufficiently interested in the subject to acquire, in favourable circumstances, a general knowledge of its historical development, and to discern . . . the firm foundations upon which the marvellous superstructure of [modern] chemistry has arisen.'

We must recognise, however, that even at this later stage a course of lectures on historical chemistry can be made very dull, and some audiences have found them repellent. So much depends upon the lecturer. If they are to be interesting to others than specialists, his lectures must not be supersaturated with detail as fine—and as dry—as powdered quicklime. They must be alive ; the historical presentation must be illumined by that glowing humanism which irradiates the whole story of chemistry, ' would men observingly distil it out.'

Although in historical chemistry we have a powerful cultural instrument, it is not every teacher who can use it. We need perhaps at least two types of lecturers in chemistry : one who is concerned mainly with the detailed presentation of specialised fields ; the other who is able to depict larger fields of the subject on more general lines and to bring out its humanistic setting in space and time. The second type of teacher would be much more difficult to find than the first. He should be a man of experience, but he would need to take an active part in the elementary teaching; for to give the young student a broad view of a particular branch of science calls for a thorough knowledge of the subject, a patent enthusiasm for it, and a power of clear and easy exposition.

Let me illustrate this precept by an example. During the visit of the British Association to Australia in 1914, the late Sir Edgeworth David, professor of geology in the University of Sydney, took a party on an excursion to examine some evidences of glacial action. At Lochinvar, ' near the grounds of a convent school,' as Miss Edgeworth David has recorded in a charming biography of her father, ' a trench had been dug to expose evidence of a glaciation. The little crowd of scientists, who had been joined by a few local residents, clustered round the trench, attracting the attention of some of the school-children. While the geologists were engaged in examining the evidence before them, the Professor noticed the small group of puzzled children, and turning aside he gave them a simple and charming little talk on the great ice age that had passed over their country.' How many of us, in his place, would have thought of doing this ? How many of us would have liked doing it ? How many of us could have done it ?

In Edgeworth David the scientist blended perfectly with the humanist. Like so many of the really great men of science, he was a man of wide interests and deep culture. In his early days he studied literature and the classics ; he attended some of Ruskin's lectures on art ; and he fostered his natural gift for drawing. Poetry was an essential part of his life, and he read it aloud beautifully. ' He had the great gift of making whatever he read live, giving the beauty of a word or thought its full value without over-emphasis, but with a sincerity that stirred the hearts of those who listened.' To this quotation I should like to add that he possessed another humanistic trait always to be welcomed in the man of science : namely, a delicate sense of humour, which, as Sir Douglas Mawson has made clear, did not desert him even in moments of great danger during that epic journey to the South Magnetic Pole. He was venerated alike by his students and Australians in general.

To sum up. During the student's undergraduate days a great deal can be done to arm him against the dangers of growing specialisation, if the influences that have been indicated are brought to bear upon him. In this crucial matter the science teacher in college or university must be an active agent. More importance should be attached to the technique of teaching from this point of view.

When the student passes to postgraduate research work upon a specialised subject he will have opportunities of developing some at least of these wider interests. For example, he should undertake a certain amount of teaching work in the junior laboratories. This will help him in many ways, particularly in cultivating his power of expounding chemistry in simple and intelligible terms. An ability to think clearly, to express his thoughts intelligibly in writing and speech, to exercise a nice choice of words, and to avoid jargon, whether vulgar or scientific, will help him not only in writing a dissertation for a research degree and coping with an oral examination ; for instance, if he goes into industry such an ability will be of great service at a later stage when it falls to him to explain to the management of his firm the essentials of a situation requiring executive action.

It is perhaps important to emphasise that a research theme of a suitable kind ought to help the student to become resourceful and to develop originality of thought, besides stimulating his imaginative and critical powers ; for the creative science of chemistry, like the creative arts, calls for a constant cultivation and exercise of originality, imagination, and critical appraisement. Unfortunately, the themes allocated to research students often fail to fulfil these fundamental requirements.

Another broadening influence that may come into play during research work was expressed picturesquely by Richard Semon, who once remarked that the importance of cultivating a wider outlook ' is to a naturalist what migration to the sea is to a young salmon.' In the course of his own studies in natural history Semon travelled widely in Australia and the East Indies. The broadening influence of travel and the contact with a diversity of countries and peoples may often be combined with the prosecution of research studies in zoology, botany and geology ; but the chemist, owing to the nature of his subject, is not so fortunate in this respect as some of his colleagues. Nevertheless in his postgraduate work he has an opportunity, which should be grasped far more frequently than at present, of migrating to another centre, either in his own country or abroad. Formerly it was the aim of the ambitious young graduate in chemistry to enter one of the continental research schools. The consequent experience of living in a new environment and speaking and thinking in a new language was invaluable. As I have remarked elsewhere : ' Continental students in those days, particularly in Germany and Austria, were traditionally attracted to teachers rather than to teaching institutions ; owing to this circumstance, and to freedom of migration from one university to another, the *Doktoranden* [in a particular school] came from a great diversity of countries and academic centres. Many of them, in their tales of peregrinations, reminded one of the wandering students of mediaeval times. To rub shoulders with men of such diverse origins and experiences was an education in itself.'

This practice among British chemistry graduates of going abroad for postgraduate research fell largely into abeyance after the war of 1914–18, owing to the development of strong schools of chemical research in Great Britain. The time now seems to be ripe however for a growing interchange of research students, and also of members of teaching staffs, not only between Great Britain and the continent of Europe, but also between Great Britain, the Dominions and Colonies, and the United States—and of course between the different universities of Great Britain.

One important point that must not be overlooked, particularly in view of present conditions in the universities, is that the proper education and training of the young scientist, with the application of the various influences that have been mentioned, presupposes the existence of adequate teaching staff and accommodation. As Sir Lawrence Bragg pointed out in the Dundee discussion : ' Our present university courses are based on the assumption that the leaders of scientific thought, who are and always will be a small band, are brought into intimate personal contact with the student . . . If the undergraduate numbers are to be greatly increased, the whole plan must be altered . . . While Honours classes were about a dozen strong, the men were known individually to the Professor and his senior staff. When numbers rise to fifty or a hundred, as they are now doing in many universities, the personal contact is completely lost.' A similar problem arises with postgraduate students conducting research work under supervision. Effective supervision cannot be undertaken by members of staff who are overloaded with teaching and administrative duties ; and even under the best conditions the number of research students that can be attached to a particular supervisor is strictly limited and must not be overstepped.

In conclusion, let us not forget that education is literally a ' leading out,' or ' drawing forth' ; but there must be something in the individual capable of being led out or drawn forth. One can neither operate in a vacuum nor animate the inanimate. The growing-points must be there. All that can be done in the home, in the school, or in the university is to give them light and air, so that they may live and grow. The number and nature of these growing-points will be found to vary from one individual to another. Sometimes they are not very evident, even to the earnest explorer. Occasionally there seems to be only one : then we have the incorrigible specialist, the man with the congenital one-track mind, who will lead a narrow but intense life. Some of the growing-points, in a normal subject, may develop ; others may become atrophied. Which of them will survive and expand will be determined by heredity, by the environment in which the individual finds himself, by the influences brought to bear upon him, and by the experiences through which he passes. ' I am a part of all that I have met,' wrote Tennyson of the great wanderer, Ulysses.

Ending as we began, upon an alchemical note, we realise that the microcosm of man has its roots and being in the macrocosm of

the outer world, with which it is one. As Salomon Trismosin wrote in the heyday of alchemy :

> Study now whereof thou'rt part ;
> So shalt thou see of what thou art :
> What thou studiest, learn'st and art,
> Of that it is thou formest part.
> All that is around without us
> Is eke within us. Amen.

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SECTION C.—GEOLOGY

GEOLOGY TODAY AND TOMORROW

ADDRESS BY

DR. A. E. TRUEMAN, F.R.S.

PRESIDENT OF THE SECTION

THE Geology Section meets this year almost immediately after the meetings of the International Geological Congress, held in London, at which hundreds of geologists from many countries have discussed a great variety of subjects ranging from geophysics to vertebrate palaeontology. It has seemed to me therefore that members of this Section may feel that an address different in character from that which has been customary may be appropriate on this occasion, and somewhat venturing, I propose to take this opportunity to look around and to see where our studies have led us. For in some words of Abraham Lincoln, ' if we could first know *where* we are, and *whither* we are tending, we could better judge *what* to do and *how* to do it.' It is relatively easy to assess the present state of geology and the ways the subject is tending to develop, but as to the more distant future, I do not claim to be a prophet, and I would at once disclaim any suggestion that I would seek to show my colleagues ' what to do and how to do it.' My intention is to look around at geology as a science and particularly at its status in Britain, and to give, for what it may be worth, an impression of some of the problems which seem to me to call for consideration.

A good geologist should, I think, always view the present in terms of the past. We are roughly 150 years on from the heroic age of our science. Until less than 100 years ago exciting discoveries were frequently being made in this country ; there were so many unsuspected fossil creatures ready to hand that early workers had no difficulty in maintaining the interest of the general body of educated men and women. In this district Gideon Mantell, who practised medicine more than a century ago in both Brighton and Lewes, described specimens of Iguanodon from the Weald, and made a considerable reputation as a geologist, though it must be confessed, by some neglect of his practice. The stimulus of Lyell and Darwin, and the survey of still wider areas which yielded (for example in North America) a great wealth of new fossil vertebrates, stirred imaginations and kept geology in the public interest for more than the next 50 years. More recently it has seemed in this country that geology has attracted less attention. This may be partly because no new monster is much bigger or more impressive than one previously known, partly because the main lines of evolution are regarded as established, and the discussion of less spectacular details arouses little interest.

But sensational finds are still being made. Even in this country (and in this county) the discovery of Piltdown man early in this century opened up new possibilities and led to controversies which still continue. Yet the problems raised by the numerous human relics recently found in East and South Africa, which have added so much to our knowledge, have not noticeably stirred up discussions of the evolution of man, except among those whose special interests fall in this field. Is it that there is general acceptance of the view that man has evolved from lower Primates, but that the ordinary educated citizen is content to wait until the full story (more complex than was once thought) has been made clear ? Fuller discussion now involves an understanding of technical details on a level which was unnecessary when the major issue, the descent of man from lower animals, was the real topic of debate, and when a single line of descent and a ' missing link ' seemed likely to afford an adequate interpretation of the facts.

That, broadly, is the position regarding geology as a whole. In this country the science does not arouse the widespread interest which was once the case and it is too often supposed that geology is a dull subject. I have known it to be hinted that the subject is nearly exhausted, apart from the filling of the smaller gaps, completing the details of a story of which the outline is thought to be already clear enough even by some workers in other sciences.

I hope that I may here take the opportunity to deny that geology is in any such condition. It is not dead or dying ; it is not waiting for a revival. It is indeed, very much alive. Even in the most limited sense, of providing a history of the world and a record of the evolution of life, we do not merely seek for material to fill odd small gaps in our knowledge. Whole major problems of evolution remain quite unsolved, and the links between nearly all the main groups have still to be found. To go no further, what of the origin of the vertebrates themselves, and of the chain from fish to amphibia ? What of the ancestry of the flowering plants ? Moreover, much of the contribution which palaeontology can make to our understanding of the mechanism of evolution, by detailed analysis of successive related faunas, has still to be developed. There is no need to confine ourselves to palaeontology. How far have we progressed in ascertaining the history of the continents ? To take one problem alone (though it comprises many others) what are the facts regarding the so-called drifting of the continents, as vigorously expounded by some as its possibility is denied by others ? Whether it is true or false, it is a stimulating idea which would have aroused a lively interest in the last century : why has it failed to do so in the last 30 years ? Perhaps there have been too many competing claims for the public interest.

Yet these, and many others, are real problems which confront geology at the present time. How can it be supposed that geology is nearly finished ? We may claim that at the present time our knowledge of earth history is expanding more rapidly than at any time since the burst of new learning which came a century and a half ago. There are more geologists professionally engaged in its study in all parts of the world. Many more fields of human activity are dependent on the success of their operations than ever before : these include the search for ores, coal, oil, water. And if we are in future to depend on atomic energy for some portion of our power, it will still need geologists to locate the sources of the raw materials. Inevitably, we shall in the future be driven to exploit deeper deposits, and ores of poorer quality ; this will require increased geological advice.

With all this increase of knowledge and with the accompanying demands for more data for economic purposes, we may wonder why geology has attracted less public attention or, as Professor P. G. H. Boswell phrased it some time ago, why there is such lack of awareness of geology in Britain ? The complete ignorance of the elements of the science shown by great numbers of people (and reflected in some parts of the popular press) sometimes reminds me of an aged African ruler to whom it was sought to explain what kind of a man I was. He was told I found coal, but he knew not coal ; he was then told (incorrectly) I found tin, and he knew not tin. So my guide pointed to a cigarette tin (full) in explanation, whereupon the old man raised his hands and said, ' The ways of God are wonderful.'

Leaving this aside, however, it would not be proper for me to give the impression that this unfortunate decline of interest in geology is being steadily maintained. Since the war we have in fact seen what may be the beginning of a re-wakening of interest in the subject. In 1947 both the Geological Society and the Geologists' Association received more recruits than in any previous time. But if matters are once more on the up-grade, we have still far to go before we reach the level of public interest shown in both the U.S.S.R. and the United States. In the latter country, when people talk of sciences, they refer as frequently to geology as to chemistry and physics. To illustrate, President Truman is reported as saying, ' Government has long recruited from academic institutions many members of its professional personnel—geologists, physicists, lawyers, economists and others with specialized training.' I will not follow his argument but merely call attention to the order in which the professions are named. May I regretfully add, it could not happen here.

Geology in Education

In seeking for an explanation of the changed position of geology in this country I think that we are bound to take note of the almost complete lack of geology teaching in schools. It may of course be argued that in most schools geology was never taught in the past. There may have been little formal instruction, but there were many teachers with a little knowledge who stimulated interest, for instance, in the course of school rambles. At the time when science teaching was less formal, and there was less concentration on physics and chemistry, the biological sciences as well as geology received more attention than in the years that followed ; with the development of specialized courses, examination standards became more exacting. This change was no doubt unavoidable if adequate progress were to be made in science teaching, but the gain was not achieved without some loss. After some delay biology succeeded in winning a place in this new order, but geology, except in a few areas (notably in Wales) was not even an also-ran.

True, the disadvantages of the new system were soon recognised by many educationists. The acceptance of each single subject as a unit in an examination meant that in a great number of schools one, or at most two, science subjects were studied. The raising of the standard in individual subjects limited the range of subjects studied, and in most schools there was little prospect of time or teachers being provided for geology. The recognition of these weaknesses led to various proposals, including the introduction of a General Science course. Following many discussions, a committee of the Science Masters' Association devised syllabuses which provided for a course of scientific study and investigation having its roots in the common experience of children and excluding none of the fundamental special sciences. The inclusion of some geology in the modified syllabus of 1938 was much appreciated, although in the present circumstances it is not to be expected that this will of itself provide a stimulus to the study of geology in many schools. It must of course be admitted that geology is taught in some geography classes, but a pupil who finds himself interested may never learn that he is studying geology.

Changes in entrance conditions at many universities have meanwhile tended to reduce the numbers of science students who take up at a university a subject not previously studied at school: the choice available at school has more frequently determined their interests. Before the recent war this had serious effects which threatened the supply of professional geologists. This situation appears to have been remedied; although I cannot but think that geology would greatly benefit from the wider basis of recruitment which would be provided if more were heard of it in schools. It is still the case, however, that far too small a proportion of students graduating in other sciences gain any acquaintance with geology. This is a matter to which I return later, but it is important to realise that few schools may be expected, in the near future, to appoint teachers to deal primarily with geology, and therefore that geology can make little progress in schools unless some of those appointed to teach other subjects have a sufficient knowledge of geology.

It is unnecessary for me to repeat the arguments in favour of greater emphasis on geology at many levels of education: they were set out in two reports of a Committee of this Section, published in 1936 and 1937. It is desirable for us to view this problem at least as much in relation to those who will not become university students as to those who will—the boy whose fulltime education will cease at 15 years of age; the student at a Technical College or any Centre of Further Education; the boy who will work with raw materials of the earth's crust (and especially the boy in a mining area); the child who will live on the land; the mature student seeking some understanding of the nature of the world and its history.

For I would emphasise that in education geology has conspicuously a double rôle. It has its cultural and its economic aspects, and there can be few subjects where both are so vital or so closely related. It would almost be true to say that there is no applied geology, as distinct from 'pure' geology. Applied geology depends immediately on the fundamentals of the science, often indeed on geological observations of an extremely simple kind: yet no piece of geological knowledge to-day could be regarded as unlikely to afford some useful economic application. A generation ago, applied geology was thought to require a special knowledge of mineralogy, for economic interest was largely directed to the search for ores. More recently, however, with the search for oil, the most abstruse palaeontological and stratigraphical evidence has become of first-rate importance; indeed, oil geology has greatly stimulated work in the formerly neglected group, the Foraminifera. In the tracing of coal seams, studies of shells and spores, and of the minute differences in the faunas of marine bands, have assumed a new value. I do not wish to suggest that the student seeking a special training for a particular sphere of economic geology does not require to concentrate, for present purposes, on lines which have proved profitable, but I do believe that ultimately his usefulness will depend to a very large extent on the completeness of his general training in geology, which should enable him to appreciate the possible applications of future discoveries to his own activities. Essentially, most economic geology depends on a knowledge of the geological structure of a part of the earth's crust, and all methods of gaining a complete three-dimensional picture from necessarily incomplete information must be available to him.

What I propose to describe as the cultural aspects of geology have profoundly influenced scientific thought during the past century; they involve discussions of which the substance at least is essential for any educated person. In this respect one of the most important results of geological investigations bears on the age of the earth. Recent researches, particularly those of Prof. A. Holmes, tend to make it possible to give with greater precision the number of years covered by particular periods, but it is not so much

the actual age as the sense of historical perspective which seems to me to be important. It is doubtful whether the ordinary man gains much from a discussion involving thousands of millions of years or thousands of millions of miles ; it is the idea of comparative ages or distances which matters most. Broadly we may recognise that just as astronomy has provided a scale of distances, so the chief contribution of geology to human thought has been a scale of time, even if some of the dates are but indistinctly marked.

It may of course be argued that an hour's reading will give an educated man all that he needs on this subject, and that to know the age of the earth as rather more than 3,000 million years is sufficient for him. Perhaps, if he understands or trusts the methods of computation, it may help him. It seems to me, however, that more important than an age in years is an appreciation of the length of time involved in each of the major episodes, a view of the history of life against the geological time scale. Speaking with some experience in teaching those who studied geology for purely cultural ends, I feel convinced that the acquisition of this time sense is not a matter merely of reading brief summaries. In my opinion it can only be gained by spending some time in the study of geological history, not because of the inherent value of the data themselves but because in no other way will the student get the impression of the slowness of great changes. This does not mean that a course of formal lectures on stratigraphy, with long tables and lists of names, is an essential background, for a series of lectures on geological history can be made exciting. But it should not be too short : it should be long enough to make it seem long, the student noting his progress on a time chart, and noting too the insignificance of historical time as compared with the stages of human evolution and of vertebrate evolution. In my own teaching experience nothing impressed me more than the profound shock with which successive classes realised, in the last lecture of a series of this type, the significance of these facts in relation to the problems of human history.

I would claim that an appreciation of earth history is necessary as part of a coherent logical system of ideas. In a similar sense, perhaps, an understanding of the structure of the earth is also significant in the cultural approach to geology, while many people in various ways derive great pleasure throughout life from that interpretation of scenery which depends upon its geological foundations. These aspects of education bear on the enjoyment of leisure, and will surely come to have even greater importance in the future.

These geological topics cannot be grasped solely by reading or from a course of lectures ; the student may be prepared to accept the authority of his guide, but unless by field work he learns how to see for himself, to satisfy himself not only that the conclusions are reasonable but that, given time, they can easily be verified, the business is only half done. In this way the student who seeks only an elementary introduction still acquires a real appreciation of the science. But, similarly, the student aiming at more advanced training is not restricted, even in the early stages, to the narrow limits of factual instruction. The wider implications of his science become familiar, and he is presently face to face with conflicting views, in connection with which he can himself begin to weigh the evidence. Perhaps the outstanding advantage enjoyed by the young student in geology is that he can, in certain fields of study, learn that reasonable people may, on the available evidence, quite legitimately hold different views. This, as I see it, is an essential part of any scientific education.

The overriding importance of field work in all geological training needs no emphasis here. It is necessary, so far as possible, that the student should see things ' in place ' and not merely in a laboratory or museum. Travel, including foreign travel, is vital to the progress of our science. The provision, jointly by the Anglo-Iranian and the Burmah Oil Companies, of funds for an annual students' tour is an innovation with great possibilities and it may be hoped that others may follow this example.

In passing, I would like to make a reference to the influence of field work on the mind of the geologist. As compared with the scientist whose work must be confined to the laboratory, the geologist gains greatly both from his contacts with nature and from his frequent opportunities to meet farmers and miners and workers of many kinds. He may climb mountains in difficult country or sit peacefully extracting fossils in a quarry to which he has travelled comfortably ; he is justifiably envied by his chemical colleagues. Without wishing to make any immodest claims for our science, I have long wondered why so many geologists have such excellent qualities : do such people become geologists or does the study of geology promote such qualities ? I am much inclined to believe that the way of life of a geologist and the nature of his studies have much to do with his qualities of mind, with his ability to take a long view and to form tolerant judgments. If this is so, ought we not to teach more geology, not for the training of more professional geologists, but as a part of a wider cultural education, perhaps as a link between scientific and more humane studies, as a

basis for a new type of synthesis? I would not suggest that other science subjects do not offer opportunities of similar development, but I would stoutly maintain that none appears more suitable than geology.

The Work of Geological Surveys

(1) In Great Britain.

In recent years much has happened to stimulate the demand for geological advice for a variety of economic purposes, both in this country and overseas. In Great Britain the Geological Survey is the official body whose prime function is the preparation and publication of geological maps and the supply of information regarding resources of ores, coal, underground water and other materials. The Survey was founded more than 100 years ago and as outline geological maps of the country were available soon after that date, the question has sometimes been asked, why has not the Geological Survey already completed its maps. Yet in some ways it is fair to suggest that the geological mapping of Great Britain is, in effect, further from completion now than at any previous time. Whereas in the early stages a small-scale survey seemed adequate for nearly all purposes, the demands for more and more precise details have made it increasingly apparent that the whole country must be mapped on a larger scale, and geological mapping on a six-inch to a mile scale has been in progress for more than 50 years. The primary survey on this scale has still to be carried over considerable areas; although these include some areas where little in the way of mineral resources may be expected, there as elsewhere 'Drift' maps showing the superficial deposits are needed. Such maps are essential for many purposes; they form a basis for soil studies, and agricultural investigators ask for more rather than less detail.

Moreover the areas where the survey would appear most complete include most of the coalfields, and here mining operations both provide new data and create an even more urgent demand for frequent revision. The use of new methods in coalfield work has made it possible for the geologist to provide much more detailed advice than formerly. At the same time, the changes in the organisation of the coal industry consequent on nationalisation have imposed still further obligations on the Geological Survey.

The Water Act of 1945 brought somewhat similar obligations. It included a section which made the Geological Survey responsible for the collection and supply of information concerning all underground water supplies. Before the passing of that Act, and especially during the war years, the Survey had brought together a great body of information on water supply, but the new Act ensures that all scientific information obtained from borings and wells is collected and made available.

In these and other ways the activities of the Geological Survey are much more extensive than at any time in the past, and it must be obvious that only a proportion of its staff can at any time be engaged on the completion of the primary six-inch survey. In fact, the Survey has so successfully carried out its functions that the demands for its help, as its recent annual reports show, have steadily increased. The war years led to a reorientation of its activities, and while its work at that time was perhaps not calculated to attract great public notice, it was essential and extremely varied. The restriction of imports gave a new stimulus to the investigation of home supplies of many materials, and in this the Survey played the chief part. The record of the work of the Geological Survey during the years 1939–44, written by the Director, was published in 1947: it shows how the staff, already well equipped to deal with the problems which arose, turned their whole attention to work directly connected with the war.

Surveys of the principal iron ore fields were extended and indicated that in the area southwards from the Humber to Oxfordshire, proved and provable reserves of ironstone together may be estimated at 2,300,600,000 tons, 'with additional possible reserves of 838,500,000 tons.' Much work was carried out in all the coalfields both as regards deep-mined coal and the location of suitable sites for opencast working. Other investigations concerned non-ferrous ores, and 'a wide variety of problems in relation to industry and industrial development. Many of these arose from the necessity of increasing supplies of such raw materials as glass sand, moulding sands, refractory materials, building sands, gravels and aggregates for concrete and other work.' They were concerned with engineering and constructional projects, including the siting of aerodromes and of surface and underground factories.

Briefly then, the Geological Survey of Great Britain is an organisation with increasing responsibilities. So far from having completed its work, it is clear that the future will bring wider commitments. The recognition of its past contribution to national well-being has added to its responsibilities; if the nature of geological enquiry were more widely understood, the calls on the Survey would be still heavier.

The development of the science in this country owes much to the Geological Survey,

but it owes much also to the unofficial, and even to the amateur worker. Fortunately there is close collaboration between the members of the Geological Survey and private workers, academic or otherwise, and it would be difficult if not profitless to trace their separate rôles. While official geologists have made many discoveries in fields of study not strictly falling within their formal duties, an examination of the history of British geology shows the importance of maintaining in this country a sufficient body of independent workers, following their own lines, restricted to no specified fields of inquiry. Perhaps the most striking illustration of the significance of the work of the unofficial geologists in the past is seen in their contributions to zoning and stratigraphical correlation. In the last 60 years almost all the outstanding discoveries in this field have resulted from the studies of unofficial workers; I need name only Lapworth, Buckman, Vaughan, Rowe and Bisat to emphasise this point. I refer to this only in order to indicate the need for different groups of workers, in geology as in other subjects, approaching problems with different aims, with great benefit to science as a whole.

(ii) In the Colonies.

The Colonial Geological Surveys, like that of Great Britain, have reached a time when their importance is acknowledged as never before, and only the comparative lack of candidates prevents a rapid expansion in their strength. The Colonial Surveys have never been adequately staffed ; at the most fewer than fifty geologists were available before the war to deal with areas totalling over 3,000,000 square miles, which works out roughly at thirty times the area per geologist as compared with the pre-war British Survey. Yet the Surveys were established much more recently, most of the areas to be covered were situated in the tropics where field work was much more frequently interrupted, and in general there was no body of unofficial geologists whose investigations could in any way supplement the Geological Surveys. During the war years the numbers of men available in most colonies fell much below even those of pre-war times. And yet at that time it was suggested in some quarters that the mapping of the geology of some colonies was nearly completed.

The absence of accurate topographical maps of many areas was a further source of delay, and in some colonies it cannot be surprising that only generalised small-scale maps are available in many areas. Yet the gains derived from such skeleton surveys as were provided should have encouraged expansion many years ago. Most of the early discoveries related to mineral resources ; Sir Edmund Teale has tabulated some of these discoveries, diamonds and manganese ore in the Gold Coast, diamonds and iron ore in Sierra Leone, coal in Nigeria.[1] He showed that ' the annual expenditure on geological survey in the Gold Coast is approximately £7,000, or one-sixtieth of the total diamond royalty.' The total value of mineral production in the colonies in 1938 was over £44 millions, and in relation to this the cost of the whole of the geological staffs was insignificant. But much of the mineral wealth discovered in those early years was found after only pioneer surveys. Such easily located deposits will soon all have been found, and more detailed investigation will be needed to reveal deposits in general at greater depths than those now being worked.

But it must be emphasised that the main purpose of a geological survey is not to find deposits of exportable mineral wealth. It is essential that attention should also be directed to the more bulky materials like limestone, clays, lignites, road metals and gravels, which may become more immediately of use to the occupants of the territories. More than all, in many areas, the importance of water supply is outstanding ; the location of underground water in many parts is fundamental to native economy. This can only be satisfactorily achieved if a complete knowledge of the structure is worked out. The relation of many soil problems to geology also provides a field of investigation of increasing importance. Systematic mapping of the colonial territories is essential, and it can only be carried out if the pre-war staffs are greatly expanded.

It is a matter of great relief to know that every encouragement is being given to efforts to promote this expansion. The Secretary of State for the Colonies (the Rt. Hon. A. Creech Jones) has repeatedly emphasised the view that geological survey is an essential step in the economic development of these territories, and has appealed to young men to come forward and train as geologists in order to take up the work. The recent appointment of Dr. F. Dixey as Director of Geological Surveys provides an adviser on these matters for the Colonial Office and makes possible that degree of co-ordination which should permit of the interchange of specialists between the colonies.

In the colonies we may therefore look forward to great advances of geological knowledge in the immediate future. Ultimately, with the growth of their university colleges, we may anticipate that the colonial peoples will themselves carry the subject forward. Meantime it may be hoped that

[1] *Quart. Journ. Geol. Soc.*, 1944, p. v.

there will be a much more frequent passage of geologists from the home country to the colonies. Apart from other considerations, a period of field work in tropical conditions is of great value to a worker in a temperate climate, enabling him to see problems of weathering and deposition in a different light. It would be good for our own studies if more of us had spent a few years in colonial work, and any scheme which promotes the secondment of British geologists to colonial posts or which brings tropical geologists more freely into touch with those at home, is bound to bring good results.

Looking Ahead

So far I have attempted very broadly to outline the position of geology to-day. I have claimed that many important problems await investigation and that geological research in this country as elsewhere is being actively pursued. Moreover, the contributions which geology can make to the economic developments in Britain and throughout the Commonwealth are more clearly appreciated than ever before. In preparation for this, there are much expanded numbers of students in all the university departments of geology. We must, however, still endeavour to increase the interest taken in our subject, for it cannot be held in these days that any science is in a healthy condition if its work is insufficiently understood by educated laymen.

So much for the present. I have endeavoured to suggest some of the achievements of geology and I have claimed that much remains to be done. What of future developments? Can we, by deciding what may be within our reach, determine what steps may be most profitable in the immediate future?

Two things seem to me to stand out at the present time. First that there will be an increasing tendency for specialisation in more limited fields of this rapidly expanding subject, and second that many of the most exciting developments in geology, as in other sciences, will probably lie on the fringes of the subject, for instance on the borderlines between geology and chemistry or geology and physics.

The specialisation to which I have referred has of course been a continuous process. Fifty years ago a good geologist might know much of zoology and botany, and professors in some universities were responsible for the three subjects; now there is a danger that some petrologists may not find any common ground with their palaeontological colleagues, that geophysics may become a separate subject and that geomorphology may be regarded as outside the boundaries of geology. This fragmentation has already occurred in geology as it has in other sciences; separate societies and separate journals have become necessary adjuncts to the development of the special subjects. All this is desirable provided that the fragmentation is not carried so far that the pieces lose effective contact with one another and the whole is never contemplated.

A similar problem arises in a more extreme form with the growth of borderline subjects. This type of problem has had to be faced in biology more urgently perhaps than in geology. But we need to secure that new knowledge gained on the fringes of geology does not for long remain unrelated to the science as a whole, and that while workers are attracted to these activities in the borderlands of geology, the central field is not neglected. In making this suggestion I am aware of the possible criticism that I am assuming that the sciences as we know them have an individuality which must persist, and that the boundaries between them must remain fixed. While I recognise the essential unity of science and the need to reconsider the limits given to what we have regarded as distinct subjects, I do none the less believe that the essential core of geology, the study of the history and structure of the earth's crust, must for many years to come remain a central and relatively independent field to which the borderland studies must be related.

The sciences with which geology has the most important contacts, and which provide fields of mutual interest, are physics, chemistry and biology. It seems probable that progress will be made most effectively in the fringes of these subjects and our own if a greater proportion of our students have more extensive training than at present in one or more of these other subjects. There are two other suggestions I would like to make: first, that a greater number of students than at present (but not necessarily a large number) should be encouraged to extend their training in order to acquire a double qualification, as in physics and geology; and second, that a larger proportion of students who will specialise in physics, chemistry or biology should pursue a course in geology, or in some branch of geology related to their own work. If steps of this kind could be taken it is probable both that geology in this country and elsewhere would extend more rapidly and that geology and geological techniques would make a much more effective contribution to science as a whole.

To these suggestions I would add a third, that there is a great need for more geologists who have some capacity for mathematics. Especially it is desirable that a knowledge of

statistical methods should be much more widespread. In some respects it is true that geologists as a whole tend to be recruited from those who lack much interest in mathematics, but increasingly our science, on the sides of palaeontology and geomorphology almost as much as on the more physical sides, is providing material which requires statistical analysis and problems where more exact solutions should be sought. This does not imply that there is no place for the non-mathematical geologist, for whom a wide field of activity remains, but in my view we ought in the future to provide opportunities for the man who will enable us to give more quantitative solutions.

Some Recognisable Growing Points

While we may not be able to see where future developments will lie, it is obvious that certain lines of development, already established, must continue. Of these perhaps the most easily recognised is geophysics, where the great advances made in the last 20 years are sufficient to indicate the more immediate possibilities. Much of the progress in geophysics has resulted from its use in connection with economic surveys, especially in the search for structures which might yield oil. The contributions of oil companies to this type of investigation have not all been made public, but the most important work done here and in India has been made fully available.

In Britain extensive geophysical surveys have been carried out, mainly during the war years and subsequently, over areas where the deeper structures are completely blanketed by a cover, up to several thousands of feet in thickness, of newer rocks. This work may be said to have been initiated in eastern England, where Dr. E. C. Bullard and others [1] carried out seismic investigations before the war and determined over a considerable area the depth of the Palaeozoic floor, making suggestions, based on such evidence from borings as existed and on the seismic velocities in the rocks of the floor, regarding the structure of the floor in that region. The Anglo-Iranian Oil Company in particular has extended these studies of the floor westwards and southwards.

Over much of the area now covered by Mesozoic rocks which rest unconformably on the Palaeozoic floor, affording little direct clue to its structure, there is scanty evidence from borings as to its depth and constitution. This extensive unknown area stretches eastwards from Bristol and Malvern to East Anglia and southwards to the Channel: surface maps of the geology are available, but if the Mesozoic rocks were removed the Palaeozoic floor would show an entirely different picture, more varied in elevation, more complicated in structure, and doubtless including other coalfields besides that which is now worked in Kent and other possible ones of which traces have been found in boring. Thanks almost entirely to the recent work of the oil companies, there is now available a geophysical survey of much of this area, showing where structural features or rock boundaries are to be found in the hidden floor. The Anglo-Iranian Company has drilled to this basement at some points, but as yet we know little of its structure. It is as if the whole of the structural features of Wales were concealed under a blanket of newer rocks, and we had only penetrated at a few points. We shall not know even the main outlines of the geology of England until this concealed Palaeozoic surface has been explored by further geophysical studies and by carefully sited boreholes.

The progress already made in the exploration of the sub-surface geology of England illustrates the importance of a close association of geologist and physicist in the development of geophysical studies. If the best use is to be made of geophysical techniques it is desirable that the geologists should know something of physics, the physicists something of geology; they should have sufficient knowledge of each subject to make possible intelligent discussion of both problems and results.

The value of such co-operation is strikingly shown in the investigations in India and Burma, recently described by Messrs. P. Evans and W. Crompton.[1] They not only make available gravity determinations at over 6,000 stations (ten times the whole number previously available in India) but calculate the anomalies resulting from the presence of varying thicknesses of rocks of low density at each station; by eliminating these effects from the actual determination the authors are able to estimate the anomalies due to deep-seated variations in density. The resulting information marks a major contribution to the structure of East India and Burma.

These and many other geophysical studies originated in work which was mainly concerned with economic geology, but we may hope for spectacular results as these methods are more widely used in the investigation of the general problems of crustal structure. I need refer only to the gravity determinations made over the ocean floor by Prof. F. A. Vening Meinesz and to their extension before the war by Dr. Bullard and Mr. T. F. Gaskell to the sea floor in the neighbourhood of the British Isles, and this year by Mr. B. C.

[1] *Phil. Trans. Roy. Soc. A.*, 239, 1940.

[1] *Quart. Journ. Geol. Soc.*, C11, 1946, p. 211.

Browne to a study of the English Channel. It will no doubt be easier to secure provision for large scale geophysical studies if they are expected to yield results of economic importance, but it is desirable that the methods should also be used to explore fields where no immediate gain is to be expected. Studies such as these are an essential preliminary to a clearer understanding of the nature of crustal structure (especially of oceanic areas), continental movements and mountain building. But we must recognise that fundamental knowledge in relation to many of these wider problems is also derived from studies in stratigraphy ; for instance, geophysical studies may help to explain the origin of mountains, but much of the structure must be learned from the rocks themselves. Here again, therefore, the close co-operation of geologist and geophysicist is needed.

Time will not allow me even to deal briefly with the probable development of many other contacts of geology with physics and chemistry. The study of radioactive minerals is certain to open still further lines of investigation ; the subject of geochemistry will expand with the wider use of the methods of inquiry developed by Fersman, Goldschmidt and others. In the field of petrology we are at a critical stage, when alternative views of the nature of so common a rock as granite are being pressed vigorously. The new information on the relations of some of these rock masses (igneous intrusions as some would still call them) adds much to our knowledge and may be expected similarly to increase our understanding.

Among the sedimentary rocks, the clays offer the widest field for future work, partly from their abundance and economic importance, partly because of the difficulties which have limited earlier investigations. X-rays, high power microscopy and other techniques are already making possible great advances.

In the physiographical or geomorphological aspects of geology considerable progress has lately been made in the investigation of erosion problems, particularly in the dating of features due to earlier stages of denudation. These are problems to which American workers have devoted attention for some time, but they have lately stimulated a number of British geologists. At this Brighton meeting it is appropriate to recall that the origin of the surface features of the Wealden area was the subject of vigorous discussion in the last century, but its interest has been greatly enhanced in recent years by the work of Prof. S. W. Wooldridge, Dr. A. J. Bull and others. There are many areas in Britain where the drainage and surface features have never been adequately analysed, and in few areas can it be said that even a tentative interpretation of the time sequence involved in their development is available.

Regarding future activities in the more biological aspects of geology I have already noted that we may hope that new discoveries will throw light on the evolution of groups whose ancestry is still obscure ; such discoveries may result from special expeditions, which are to be encouraged, but they must depend, partly at least, on chance. We can look forward much more confidently to some of the probable developments in the study of the more abundantly represented fossil groups. In the first place we may expect the continued flow of descriptions of new forms, and the introduction of new names. A century or so ago it was hoped to provide illustrations of all British fossils, but all the efforts of the intervening years have failed to close the gap. We can now at least appreciate the task which faces us, as we seek to understand the faunas and floras of what we may regard as many hundreds of separate episodes ; the hope that a geologist might be able to name his fossils at sight faded long ago and he now hopes to carry in mind no more than a few characteristic species occurring in the rocks on which he is engaged. But the description and illustration of the numerous forms must be pressed forward. The work carried out for a hundred years by the Palaeontographical Society must be maintained and if possible extended. In these times of increased costs this can only be done if this and other societies receive greater financial support. Otherwise the status of British palaeontology will suffer, and the foundations of our stratigraphical geology will be weakened.

Another direction in which I hope we may see great progress in palaeontological studies is the more detailed investigation of successive and related faunas, especially those represented by abundant specimens. From the analysis of variation in such communities we may hope to learn more of the ' mechanics ' of evolution. Moreover, such studies (including statistical studies) are necessary for the adequate description and comparison of varying groups, both for their use in correlation and for their understanding in taxonomy. Within the next decade more intensive studies on these lines may provide a new approach to taxonomic problems, especially of invertebrate fossils. We continue to use a binomial nomenclature for our fossils, but some of us believe that some alternative, or some supplement, to this system is essential for those dealing with forms which are abundantly represented by variants occurring at many closely spaced horizons. In a single bed the faunas present problems not very

different from those met by students of modern faunas, but when successive ancestors or descendants of these faunas are also to be classified taxonomic problems of a wholly different character are introduced. Any attempt to meet these problems by recognising such divisions as sub-species merely changes the scale. Where faunas so constituted are concerned existing taxonomic procedures can provide no more than a makeshift classification; amongst such intergrading forms represented at successive horizons it may be impossible on any morphological basis to make valid subdivisions, and a new approach to nomenclature is needed. I think that it can only be provided by the statistical examination of material of this kind.

In this rapid survey I have attempted to assess the probabilities of advance along widely different lines. In some we shall need to use techniques developed in other sciences, but I have tried to suggest that those who work in the borderlands of geology should be in close touch with the main body of geological workers, bringing their results into relation with the whole range of geological knowledge, if our understanding of the structure of the earth's crust is to be advanced rapidly. In this country our most important contributions (and they have been very significant ever since the time of William Smith) have been in the field of stratigraphy, the 'heart of geology' as it has lately been called by Dr. J. M. Weller. In that field, throughout the British Commonwealth, much still remains to be done. The making and improvement of geological maps is perhaps our central activity, on which most other branches of geology must converge. While any of these branches make progress, we should be able to make better and more useful maps. The more closely we can link these various activities the more rapidly we may expect to solve those problems of mineral resources on which we depend and to understand the history of the earth on which we live.

For I would repeat that the study of geology has these two aspects. We must train geologists because we need them, but at the same time we should seek to use geology as a part of a wider education for many besides those who still become professional geologists.

SECTION D.—ZOOLOGY

UNDERGRADUATE ZOOLOGY

ADDRESS BY

PROF. H. GRAHAM CANNON, F.R.S.

PRESIDENT OF THE SECTION

THE task of a President of Section D becomes progressively more difficult. When I attended my first British Association Meeting at Edinburgh in 1921, it was reasonable to assume that all members of the Section could not only follow the points raised in the description of any zoological work but would be able to evaluate them and see their significance to the general argument. To make this assumption nowadays, in these days of incredible specialisation would be foolish. For me to assume that, if I were to deliver to you an account of all my work on the minutiæ of details of the entrails of Ostracods and other such beasts, you would be able to follow me, that would be not only foolish but conceited. I will confess at once that I realise that my own morphological studies are much too unfashionable, and we zoologists along perhaps with all our fellow scientists are very much creatures of fashion. In the old days, the President of Section D was a leader of that fashion. He could describe his latest researches in the light of the most fashionable developments of zoology and be certain that all his audience would appreciate its frills and fripperies.

On the other hand, I feel it is incumbent upon a President to speak on some definite aspect of his professional work in which he has a real interest and on which he has pronounced views. If he has a message to deliver, so much the better, for no better time could be chosen than this, when the greater number of zoologists in the country are gathered together to hear how things are developing in zoology generally. I have decided therefore to follow the precedent established by my distinguished predecessor, Professor Graham Kerr, and speak on a general topic—the teaching of zoology to undergraduates—a problem which by virtue of the fact that I have now occupied a University Chair for longer than I care to remember enables me to put forward views based on a reasonable amount of experience. Much of what I have to say, I am certain, will not find favour with many zoologists and even more so with workers in other sciences, for I am greatly perturbed about the present critical state into which our subject had developed. I feel sure that unless there is a definite change in the manner of educating our undergraduates, zoology will follow those other natural sciences in which it is the fashion to regard elementary teaching at the university level as something to be avoided at all costs and conveniently to be relegated to the school years.

In speaking to you, it is important to remember that I speak as a Redbrick professor. The conditions in the Redbrick Universities, in the Scottish Universities and in the London Colleges are markedly different from those existing in the Universities of Oxford and Cambridge. Now, while it is right that we should look to our two ancient seats of learning for stimulus and guidance in our teaching, I think it is the non-appreciaiton of these differences that leads to many weaknesses in our provincial teaching. What can be done in the leisurely atmosphere of Oxford and Cambridge with such cultured ease cannot necessarily be copied in the more hectic atmosphere of our Redbrick Universities. But there are many more undergraduates in the Redbrick Universities than there are at Oxford and Cambridge, a fact so often forgotten, and so when I decided to talk about the problems of teaching zoology as they affect me at Manchester, I felt justified in settling the title of my address as simply Undergraduate Zoology.

In order to understand some of our present difficulties it is necessary to consider very broadly the main developments of zoological research and teaching during the last fifty years. At the beginning of the century the immense output of zoological work which had been stimulated as a result of the publication of the *Origin of Species* in 1859 was beginning to show a marked sterility. The vast amount of anatomical, taxonomical and embryological work seemed to be leading nowhere particular

except as leading to a more and more complete knowledge of the classification of animals. The museum influence was pre-eminent; the identification and classification which was and should be the chief interest of the museum official became very largely the main pre-occupation of the university teacher and the unescapable curse of the poor unfortunate undergraduate. This influence of the museums lasted well into my own undergraduate days during the First World War and one has only to look at what few modern text-books of zoology there are—or better still, at modern examination papers—to realise that that influence is still with us and is producing an effect out of all proportion to its significance.

About this time there must have been an unconscious revolt against the way that zoology was developing both in this country and in America. It seems to have become evident, to academic zoologists at least, that all their efforts at classifying animals had not led as far as had been hoped in throwing light on the mechanism of evolution, and further, that the classification of specimens, practically always dead, threw little light on how those animals lived. A changed attitude or, as I refer to it, a rebellion, developed, and I like to think that one of the more important contributory causes of this action was the publication in 1908 of Gaskell's *Origin of Vertebrates*. This must have come as a shock to the more sober-minded zoologists. Here was a physiologist who, by using the zoologists' own tools of comparative anatomy, had been able to upset their favourite tree and show that vertebrates, after all, had evolved from a creature more like a spider than a segmented worm—to us nowadays with our knowledge of functional morphology, a fantastic view—but to those who only thought in terms of structure *qua* structure such an ebullition from their colleague in the physiology department must have appeared rather like a bull in a china shop.

This new outlook took two main trends. First, zoologists seized on the newly rediscovered law of Mendel. It became the panacea for all their problems. Here was a means of analysis which would illuminate all those elaborate phylogenetic trees that they had built up so laboriously by means of their painstaking anatomical and embryological researches. Some, I think perhaps the majority of, modern workers believe that these early hopes have been justified; but I am not included in that majority. And secondly, the science of experimental zoology became established. At first it would appear to have originated largely on the Continent, as a means of investigation, by changing and controlling the environment, of the developmental processes of animals, and this aspect of experimental zoology has continued and culminated in those brilliant researches—perhaps the most spectacular ever obtained in the whole science of biology—of Spemann in his analysis of amphibian embryology. But over here the result of this trend was not to be found so much along the lines of what we now conveniently call Entwicklungsmechanik but in another direction. For controlling the environment of an animal, whether embryo or adult, of necessity led to the study of the physiology of that animal, and thus there arose in this country just before the First World War a marked interest in comparative physiology. This in its turn was largely stimulated by the concurrent development of the new science of biochemistry. Then came the Great War in which we suffered so grievously. Jenkinson, Geoffrey Smith and Darbyshire, to which we must add the name of that very great zoologist, Leonard Doncaster, all these were missing when we started in the early twenties trying to get back to normal. It is of sad interest to speculate how British zoology would have developed if there had not been this gap. Personally, I do not think it would have altered the trend that ultimately *did* take place for they were all experimentalists, but that does not diminish the magnitude of the loss to British zoology.

I have now sketched what appears to me to have been the state of affairs throughout the country in the early twenties. It is this date which is significant to us in considering the present position in the teaching of zoology in the universities, for, unlike the Second World War during which undergraduate teaching continued uninterrupted, there had been in 1920 a complete gap of nearly six years during which teaching and research was almost at a standstill. There had been in addition the revolt that I have just described against the more orthodox anatomical approach to zoology smouldering since the beginning of the century. Is it surprising therefore that when things started up again complete rebellion broke out? Comparative anatomy became the one subject to be avoided and all energies had to be placed in the newly discovered experimental method.

The measure of the influence and extent of the experimental school, and of the narrow specialisation which was an inevitable result of the changed outlook, can be gauged in a number of ways. A comparison of the type of paper published nowadays in the Proceedings of the Royal Society with those published before the First World War reveals at once that to-day practically all are experimental and by far the greater proportion are understandable only to the very few specialists who

happen to be working along the same lines. The Society for Experimental Biology, founded in such a modest way some twenty-five years ago, is now the largest and most active of all the biological societies. Its meetings extend over days, but again the specialisation has gone to such an extent that separate days have to be devoted to separate aspects of this already specialised subject, a quite different state of affairs from when we started. Or again, how often in the journal *Biological Reviews* does there appear a paper on orthodox zoological lines? There certainly have been more of recent years but they are still very few and far between. However, this journal illustrates, I consider, perhaps better than anything else, the appalling specialisation into which experimental zoology has developed. Whereas a generation or two ago any biological review would be understood at least in the main by all zoologists, that is certainly not the case now ; only the specialist can really appreciate what is written by the specialist.

Now the results of recent researches form the material on which the undergraduate should be brought up. They are the symbiotic links between teacher and pupil which are essential to the proper development of both. Naturally, therefore, since the majority of modern teachers have been brought up in the experimental atmosphere and since the greater part of modern researches are of an experimental nature the undergraduate of to-day is apt to get a very unbalanced idea of his subject and this is all wrong. I contend rather that modern research work should be used in relation to more fundamental zoology in the same way as vitamins are fed along with the basic animal foods. The vitamins alone are of no use and neither are the abstruse profundities of modern experimental technique without the solid proteinaceous foundation of comparative anatomy to allow them to do their work.

When lecturing to an undergraduate class especially in their first year, there is nothing more stimulating than to commence the lecture by trotting out some latest development in research. It stimulates the students, it excites them and makes them much more ready and able to appreciate the more fundamental and substantial part of the lecture.

I have been talking about the more fundamental side of zoology and contrasting it with modern experimental work. Now I want to make it abundantly clear that I have no desire to see a return to that type of comparative anatomy which I have explained was prevalent at the beginning of the century. That aspect of zoology which I deliberately described as the museum attitude is, in my opinion, completely sterile except in museums. It divorces structure and function and while it enables the taxonomist to classify his animals *ad nauseam*, it tells the zoologist precious little about how the animals lived. We are still very much encumbered by trimmings of this Edwardian zoology. What few textbooks we have are largely written on this basis and all our questions in practical examinations, which we still set and which begin ' Identify giving reasons . . .' are typical of the period. We have all suffered either as a student in trying to learn meaningless classificatory tables or as an examiner in trying to evaluate such answers as that the skull of an elephant cannot be a sponge as it contains no collar-cells ! By all means teach the student to recognize a Primate skull, teach him the functional significance of the dentition, but is it really necessary that he should know that a marmoset has one more molar than a monkey—or is it one less ?—I always forget which ? Let the student know about the biramous nature of the Crustacean limb because it is the fact that it is biramous and not uniramous that led to such exciting functional possibilities in the evolution of the group. But why should the poor undergraduate have to encumber his mind with whether or not the maxillulary exopodite is present or absent, and if present, whether or not it points forwards or backwards. I always remember this from my student days —I could not see why I had to learn it. I did not realise then as I do now that it was simply to ensure that I should be able to recognize the various types of the Crustacea Peracarida. It was knowledge therefore to be learnt but only of real use to the museum official. But, and here is the fatuity of the whole business, the museum official rarely, if ever, used such information. He did not look at the maxillule to distinguish a wood louse from a mysid or a cumacean from a tanaid. He distinguished them at a glance and that is my criticism of the greater part of the diagnostic zoology of the Edwardian period that still too much encumbers our curricula. The distinguishing features by which students are taught to recognise the various types of animals are, as often as not, trivial, the actual recognition being made by a whole complex, or, in other words, the general appearance of the animal.

I have stressed this diagnostic attitude perhaps unduly, but it is to my mind a fault that can be easily remedied. In addition, there was a much more serious outlook, what I call static morphology, which rendered useless much of the material which we imbibed as students. I need only mention such stories as those that we used to be told about the evolution of fins in fishes, or tails, or jaws,

or the fate of the ear ossicles or the evolution of gills in lamellibranchs—all this and not a word about function. Nowadays, fortunately there is little need to worry about this side of zoological teaching. All these stories are unravelling themselves or rather are becoming translated into terms of functional morphology in the light of modern zoological research—sometimes, but not always, experimental. Let us take some examples. The old stories that we were taught about evolution of fins were based largely on palæontological researches and palæontologists are principally concerned in placing their specimens in rows or sequences, much more so than in finding out how they worked. But nowadays, largely through the stimulus of James Gray we know quite a lot about their functions and interrelationships. This is the sort of thing the undergraduates relishes. If he knows how the fin works, he appreciates why he should learn its anatomy. If the student sees the significance of the position on the body and the shape of the fin, he understands why he also has to learn about its heterocercal tail, for as Gray and his workers showed, these two points, which to many of us here were certainly taught as two doses of medicine to be taken separately, are in fact closely interrelated.

And then as a second example take that extraordinary case of the Lamellibranch gill. The anatomy of the various types of gills in the Lamellibranchiata has been known in detail since the publication by that very great zoologist, Ridewood, in 1903, of his monograph. The whole of this paper like all his published work is stamped with amazing erudition and yet there is not one word as to the method of functioning of the gill. If you read the account of this work published in Sedgwick which is, after all, still largely a standard text-book, you will find that there is no mention of function. It is simply assumed that the gills are respiratory which, of course, largely they are not, and the matter is left at that. It was very difficult and monotonous for the undergraduate to have to learn these anatomical sequences. But now, largely due to the pioneer work of Orton, we know the real significance of the so-called respiratory organs of the Lamellibranchs. It is the easiest thing in the world to demonstrate how they work and to see the significance of the various types of cilia and the occurrence and arrangement of the mucous glands which were all described long ago by the earlier workers. Here is something which has an obvious purpose. It teaches the undergraduate much more than the mere classification.

The cases I have mentioned have been solved largely by the experimental method, by observing the living animals, or even models of them, in various conditions. Now I want to emphasise that similar advances in functional morphology can be made and have been made by a strictly morphological approach, using in fact only the classical methods of research which were employed at the beginning of the century, and for this purpose I am going to talk about some of the work done in my own Department either by my colleagues or by myself.

If I may refer once more to those days when I commenced my own researches in the early twenties, there was then prevalent an idea, entirely misconceived, that all the main problems of anatomy which it was reasonable to assume were capable of solution had, in fact, been solved. There was nothing of consequence left to be done and I think it was this belief that added fuel to the flames of revolt. In two groups in particular it was thought that no further advances could be made until entirely new methods of anatomical research were evolved. I refer to the Echinodermata and the Arthropoda. In both it seemed to be tacitly assumed that because of their hard skeletons they were not amenable to ordinary methods of section cutting. Now in the Echinodermata, J. E. Smith has carried out his excellent work on the functional morphology of the nervous systems without using any new method at all. He merely paid adequate attention to fixation and then used ordinary standard methods of decalcification and staining. In my own work and that of my colleagues on the Crustacea, we have never used anything except the old traditional methods of microscopical technique simply because there has never been any occasion to do so. The only thing new, if it can be called new, about *my* methods, is that I use thick sections or slices rather than thin, and this paradoxically enough is a reversion to the old methods of hand-cut sections rather than something novel.

As for there being little work to be done, I soon found that, in fact, on the anatomy of the Crustacea very little had been done. To take three of the groups on which we have worked, a certain amount had been done on the internal anatomy of Copepods, less still on that of Ostracods, while practically all that was known about the inside of a barnacle was published by Charles Darwin in 1854. Now by studying the typical members of each of these groups we have been able to work out the structure and arrangement of all the important internal organs and then without resorting to experimental technique to predict with complete confidence how the organs worked.

I am well aware that it is fashionable

nowadays, especially at our older seats of learning to accept no statement as to the method of functioning of an organ or as to the functional significance of a structure, until that statement has been tested experimentally. Of course, as regards all anatomical work this view has always been quite wrong. When a nerve is seen running to a muscle it is *assumed* that it represents the nerve supply of that muscle—it is not tested experimentally. When a blood vessel is discovered and in that blood vessel there are valves it is deduced without further experiment that blood passes along that vessel in a direction determined by the arrangement of the valve. Anatomists have adopted this view since the days of Harvey. If such assumptions and deductions were not made from the results revealed by our dissections the whole of the study of physiology would become, from the practical point of view, impossible.

I do not intend here to go into details as to how the application of these simple methods has yielded results in our Crustacean studies as I shall have an opportunity for that later on when I hope to show you that without any experimental work I have been able to establish, not only that a barnacle has a complete canalicular blood system but to show the course of the circulation and the method by which, without a heart in the true Arthropodan sense, the blood is circulated round the body.

There are two special cases, however, that I want to deal with. First, there is the case of giant nerve fibres and their significance. I think it is now generally conceded that giant fibre systems occur in those animals which exhibit an escape reaction, that is, in animals which, on being disturbed, make a sudden violent movement away from the centre of disturbance, for example, the earthworm and the crayfish. I am mentioning this case particularly because there is an erroneous idea that this discovery emanated from the experimental schools whereas, in fact, it arose from pure anatomical investigations and in the following manner. I was working on the internal anatomy of a typical Cypridinid Ostracod and I noticed that the immense muscles in the base of the antenna were enervated by five giant fibres. Now Cypridina on being disturbed makes immense bounds forwards, so violently in fact that it is impossible to catch it in the sea with a hand-net. I have even seen a Cypridina break through the surface of water in its efforts to escape. As this movement is brought about by the backlash of the oar-like exopodites of the antennae, it suggested that the giant fibres were serving the escape reaction. However, the more illuminating discovery was made when Miss Lowe (1935) was working out the anatomy of the Copepod Calanus. This form has a marked escape reaction which had been recorded by high-speed cinematography by Storch. It consists of a sudden backlash of the long multi-articulate antennules and at the same time of the biramous paddle-like trunk limbs. Now Miss Lowe showed that all those muscles which were used in the escape reaction, *and only those muscles*, had a giant fibre supply. Thus the giant fibres ran to the muscles which moved the trunk limbs backwards but not to those which brought the limbs forward again after the escape reaction had been made. About this time I was working on the anatomy of the deep-sea Ostracod, Gigantocypris. Now this form is a Cypridinid but a very peculiar one. To begin with, it is immense, but also, and this is the significant fact, it is almost spherical. This being so, it does not require much knowledge of mathematics to know that it could not possibly move quickly through the water. In other words it could not exhibit an escape reaction. I soon found that corresponding to this it had no giant fibre system. Some time later (1938), J. Z. Young published the statement that a squid has a giant fibre system, and, in another paper, that the octopus has not. But a squid on being disturbed moves away violently while an octopus stays put and relies on its colour changing mechanisms. This therefore fitted in completely with our own observations and the point I want to make here is that all this analysis was carried out on anatomical rather than experimental lines.

And now, for the second case, I shall talk about my own work on the Crustacean limb. I am doing so partly because I want to emphasise still further that the classical methods of morphological research are still capable of yielding new and valuable results, but also because this problem does demonstrate more than most the sterility of the museum attitude and even the false scents that may develop as a result of a static outlook on morphology.

I was brought up by that great teacher Borradaile on a phyllopodium. He taught that since an annelid parapodium is flat, then those limbs such as the trunk limbs of Chirocephalus, the Fairy Shrimp or Nebalia, or the maxilla of the lower Malacostraca which are also flat, must represent the primitive limb of the Crustacea—a deduction based entirely on structure. This led naturally to Nebalia becoming the most primitive of the Malacostraca and how convenient it was that Nebalia, as was then thought, possessed one more segment in its trunk, another primitive character, than all the other Malacostraca. And then the Fairy Shrimp belonged to the

one Group of Crustacea in which the number of trunk limbs was variable and this anomomerism Lankester had demonstrated again represented a primitive character. It all seemed to fit together so well and yet it led nowhere. Starting with Nebalia or Chirocephalus as the most primitive forms it was extremely difficult except by the most far-fetched imaginations to evolve anything from their limbs. The main difficulty was that if the phyllopodium was indeed the primitive limb how did the simple biramous paddle, such as we all know occurring on the abdomen of a crayfish, arise and also what was the meaning of the marked differences in shape between the phyllopodia of say the Fairy Shrimp, Nebalia or more particularly Apus. The trouble, of course, was that all these phyllopodia which as their name implies must be flat leaf-like structures were, in fact, only flat and foliaceous because they had been removed from the body and mounted flat under a coverslip. I am not exaggerating when I say this and when I add further that the trunk limb of the Fairy Shrimp is no more flat than is the great claw of a crab—if anything it is even more robust for at its base it is as thick, fore and aft, as the whole segment on which it occurs.

A study now of the limbs of these phyllopodous forms, not isolated from the body, but as they occur on the animal, so that their spatial relations to each other and to the trunk could be studied—a study sometimes made from sections and always from sagittal halves of the whole animal—showed that in all there are on the outer or exite side of the limb a series of flaps. Further by merely assuming that since the limbs *were* limbs they would be moved backwards and forwards, and, without even using our modern knowledge of metachronal rhythm, it was evident at once that on such movement the spaces between the *successive* limbs—what I call inter-limb spaces—must enlarge and diminish periodically. Putting these two facts together it became clear that the exite series of flaps form valvular structures and it was then a simple matter to deduce that they acted in permitting a passage of water between the limbs in one particular direction. Thus a current-producing mechanism could be deduced by studying simply the anatomy and spatial relations of the limbs to each other and to the body. In precisely similar manner it could be deduced from the anatomy of the inner edges of the limbs—the endite series—that these structures formed a partial barrier filtering particles from the current which had already been argued. In Hemimysis, Dr. Manton and I followed this line of argument in regard to the maxilla and deduced that it was a filtratory limb. We then proved the point by feeding iron saccharate to the animal and finding from sections that it was deposited as a filtered residue on one face of the endite plate of the maxilla. Now this filter plate consists of a series of closely parallel setae. Along the edges of the setae are setules but these setules do not lie in the plane of the plate but project towards one face, and this, as might be expected, is the face on which the residue is filtered off. Here now is a morphological character which can be used in the study of *other* forms to diagnose not only the filter plate but the direction of the current through that filter. In this way, I have been able to work out the complete filtratory mechanism, the most perfect I have ever studied, in the Ostracod Cyclasterope, although, as this is an Indian form, I have never been able to study it alive. Similarly, I have worked out an inexplicable filter mechanism in the deep-sea form Nebaliopsis. I cannot see what its significance is but I am quite certain as to its existence.

I hope I have now demonstrated to you that morphology in the light of modern functional advances made from both the experimental and the anatomical outlook is now far from being the much-despised aspect of zoology that it became at the time of the great rebellion in the twenties. It has taken on, if I may be pardoned the expression, the new look. The undergraduate nowadays comes away, or should come away, with a knowledge of living things and not merely of the structure of corpses. With his wider and more enlightened outlook, he can in his post-graduate studies, if he so desires, specialise on the functional side and become an experimental or comparative physiologist or, on the other hand, he can concentrate his interest on the structural side and become a comparative anatomist. For now, knowing the functional significance of the structures he is studying, he can produce with confidence a reasoned evolutionary story.

Now in the old days the whole of the undergraduate curriculum consisted of a series of lectures dealing group by group with the animal kingdom and this together with a relatively small amount of general lectures completely filled the time-table. With the swing of the pendulum to the modern experimental outlook, I am afraid this is far from being the case in many Universities. It is my contention that we should revert to the old state of affairs. I am certain, and I speak after considerable experience, that it is possible for a reasonably experienced staff in the three undergraduate years adequately to cover the whole animal kingdom and at the same time to impart to the students a sound knowledge of all the main developments in up-to-date research, without the

establishment of those lengthy specialist courses which are to-day becoming so popular. About the latter, I shall have something more to say later on, but first let me sketch what I consider should be the type of instruction and how it should be given within the three undergraduate years.

In all Redbrick Universities, the first year students in the zoology department are a very mixed group—scientists, pharmacists, dentals and a large number of medicals. All these are to be provided with an introduction to the study of zoology and the first two terms of the year should be devoted to this. I cannot see any reason why a special course should be provided for any one of these classes of students. All require a foundation and the proper foundation to the study of zoology is the same whatever the future career of the student may be. Now such a heterogeneous class would contain all sorts of scholars—some will have done zoology at school for some years—others will have done none at all but will have specialised in the physico-chemical side. Sometimes there will be that rare but valuable student, the arts scholar, who has seen the folly of his ways and has switched over to science. To me it is abundantly clear that the professor should always be in charge of this introductory class. He is, or should be, the most experienced of his staff. He has to cater for all the different types but, at the same time, must not assume in any of them any special knowledge. It is difficult, of this I am well aware, but it can be done and I will confess that I find it a most exciting, and to me, valuable part of my duties. It is in these first two terms that the professor can introduce so much of the latest research and, of course, introduced here, when a student is just realising the difference between school and university, it becomes so much more valuable than if introduced later when the undergraduate has become a somewhat blasé final Honours student.

I disagree profoundly with those of my colleagues who consider that the professor should lecture only to the most advanced students and usually on the most specialised subjects. The professor should not be a narrow specialist or rather, he should not be only a specialist, he should have his own ideas on a very wide aspect of the principles of his subject and it is these principles that he should hand on to his students. I know that in the ancient universities, which by virtue of their collegiate institution are able to employ relatively large teaching staffs, it is often possible for all the elementary teaching to be taken over by some more junior member of the staff who happens to be prepared to devote all his time to such teaching. But what can be done at Oxford and Cambridge cannot necessarily be copied in the Redbrick Universities—a point so often overlooked, I am afraid, by many migrants from our ancient seats of learning.

Apart from this, I feel also that if the student has 'sat under me' I want that statement to have some meaning, I want him to go away having, at least, heard my outlook on things in zoology. It matters little to me whether or not he is *au fait* with all the details of my particular researches: what does matter is that he should know my views about major problems. My attitude towards morphology, for example, rather than my morphological discoveries—my views on the position of Mendelism in modern genetics—or my beliefs in matters embryological—all these are big problems towards which it is important that a student should have some definite attitude. Whether or not an undergraduate accepts my views is of little importance; what is important is that I should have had the opportunity of putting my views to him as early as possible in his undergraduate career so that in his final years he will have the opportunity of testing them. For me to hand over this essential first year work to one of my juniors would appear to me simply as a dereliction of my duties.

However, a far worse attitude than this to the first year teaching is the tendency, which is now becoming so widespread, to push the intermediate teaching on to the schools. There undoubtedly has been what has been described as an invasion of the university syllabus by the schools, prompted largely by the type of scholarship paper often set by the examiners. But now, instead of trying to combat this, it is being encouraged. The schools cannot be blamed for their attitude, but on the other hand I do not think that we zoologists are the real culprits. At least we are not primarily to blame for the absurdly advanced standard of knowledge which is nowadays expected from the sixth form scholar. If you will examine the Cambridge scholarship papers for the last thirty years, you will find that those in zoology are, and always have been, at a reasonable level, those in physicochemical sciences have advanced, but mainly through the inclusion of more mathematical aspects of the subject, while those for mathematics have advanced in a fashion that can only de described as ludicrous. Now schools will naturally teach to the level of the highest scholarships awarded and these are the Oxford and Cambridge scholarships; and in that teaching it is the scholarship that sets the standard, not the subject. As one subject advances so all the others tend to follow—of this I am certain. The schools cannot be blamed for

this. I have nothing, of course, to say in favour of those scholar-producing factories where the whole energy of the school is devoted to obtaining the maximum number of university scholarships, but all schools must naturally aim at a reasonable degree of results. There was a time, when the Norwood Report appeared, advocating the abolition of the H.S.C. examination and its replacement by a less advanced but much wider examination, when some of us thought that this would force the older universities to lower the standard of their scholarship papers. But the Norwood Report is now a thing of the past, and for all intents and purposes we are back where we started, with the H.S.C. standard trying hard to follow the pace set by the Oxford and Cambridge scholarships. However, as regards the schools, having taught to this high level, I can understand them expecting their pupils to be excused the first year of university study of those subjects in which they sat their scholarships. Now this may be possible in physics and chemistry and mathematics, but I maintain most emphatically that such an exemption should not apply to the biological sciences. After all, to use a Royal Society expression, the A series of sciences are the tools of the B series while the reverse does not apply. A student graduating in either of the biological sciences to-day knows a considerable amount of physics and chemistry and mathematics—he will not graduate otherwise—but in my experience graduates in physics and chemistry usually have not the vaguest idea to what a living organism means, unless, of course, they have had the sense to take biology as a subsidiary subject. As I see it, mathematics can be studied alone even up to the highest levels and so more and more may be pushed back on to the schools provided only that there are school teachers capable of teaching up to the higher levels. Chemistry and physics can be studied more or less independently, but only as long as mathematics is studied at the same time. There is thus a limit to the amount of knowledge which can reasonably be expected from undergraduates at their entry to the university from school—a limit determined by the amount of mathematics which it has been possible to instil into them. For the proper study of biology, however, a concurrent study of chemistry, physics and mathematics is essential. It cannot, therefore, or should not, be expected that boys coming to the university with a school training in biology will have the same real understanding of their subject as they will have in say chemistry or mathematics. They will only get that real basic understanding which is so essential if they are going to continue with the subject, after a synthesis in which the elements of all their science subjects have been integrated and this is where, I maintain, the wide experience of the university professor is essential.

What is the reason behind this desire to follow the physicists and chemists and shift the responsibility for the intermediate teaching on to the schools? The answer is not far to seek. It is simply to allow for more and more time in the second and third years in which to introduce specialised courses. Now I am firmly convinced that after allowing for a modicum of general lectures—lectures usually but not always without associated practical work—there is left just sufficient time to cover adequately all the various groups, not excluding the so-called minor groups, in the animal kingdom. This is, of course, always allowing sufficient time for the practical study of the animals—time when by far the greater part of the anatomy and taxonomy of the groups can be dealt with by the student under the supervision of the demonstrator—time when the student can embed and cut sections of his specimens and study their minute anatomy and histology or time that he can spend in the departmental museum studying the whole range of types in a particular group. If this is done, if time is not wasted in lectures by giving elaborate accounts of anatomy or details of abstruse classifications then the lecturer is able to devote more and more time to the functional morphology of the group and at the same time to include all the cases of recent research which happen by chance to affect the group on which he is lecturing. In fact, I cannot conceive how any lecturer can possibly give a course of lectures nowadays on any group *without* including all the latest developments in research. During the past generation in practically every group there has been some exciting new functional morphological discovery. To my mind these discoveries find their right place in the lectures on the group of animals to which they refer. Let me take an example to make my point clear. A discovery relating to respiration in a certain group should be dealt with in lectures on that group and not in a specialised course on respiration which would of necessity have to refer to recent work on such widely differing groups as Coelenterata, Insecta, Crustacea and Polychaeta, and hence could only properly be understood by students when they had completed a survey of these groups.

Of course any normally intelligent student should be able to follow what is said to him in any lecture on the most abstruse subject, that is, provided the lecturer is at least coherent, but that is not learning. For the

lecture to fulfil its essential function the student should be able to marshal what he hears, to evaluate it and correlate it with the related knowledge with which he is already acquainted. I am putting this point in some detail as I want to demonstrate how futile it is to imagine that students can really appreciate the most advanced specialist subject before they have completed at least an elementary study of all groups in the animal kingdom. Of course, what in fact happens so often is that the students can—and do—learn their lecture notes by heart. Of this I have had ample experience, but this is hardly education. I cannot entirely blame the students for nowadays final examinations have become so much a test of the lectures given that if the student finds the matter far above his head he still cannot afford to omit any set of lectures.

If what I suggest is done, then, provided always that it is backed up by the general lectures I have mentioned, there is no need at the undergraduate level for specialised courses. These general lectures, I maintain, should again be introductory, giving, not details of the latest experimental researches, but rather the principles on which the experiments of these researches are based. There should be a few lectures on cytology, a few on genetics—yes, despite the profundities of the Neo-Mendelians, it is still possible to deal with this matter adequately in a few lectures—and so on. I have just suggested these topics, but clearly departments would differ in their choice of subjects. One aspect I am certain, however, should always be dealt with and that is the principles underlying experimental and comparative physiology, and here associated practical work is of great value. If, say, one afternoon a week for a term or two is allowed, it is possible for the student to carry out all sorts of most stimulating experiments. He can be taught for example, not the latest views about some elaborate enzyme complex but can be shown what a simple enzyme can do. He can learn how to measure the *p*H of a solution and can be shown simple cases of the effect of varying this factor in a solution, or he can be shown a simple nerve-muscle preparation. In fact, in these ten or so afternoons, he can be taught all those simple physiological stories which his fellow medical students would be taking in their stride. My complaint is that usually the zoology student is expected to tackle physiological problems far more difficult than the medico without any fundamental training. He is, in fact, expected to start in at the top.

I have now pointed out what appear to me to be the most misguided tendencies in our present system of teaching zoology. Are there any indications that things may, according to my views, improve? No, I think that everything points in the reverse direction. All my forebodings are that matters will continue to get worse. Our undergraduate teaching and hence our degree examinations will continue to include more and more advanced specialist work to the exclusion of the more important fundamental aspects of the subject. Our final Honours degrees will become—if they have not become already—merely a test of memory of advanced lectures rather than a searching test of understanding.

There is one exception to what I have just said. In the London University External degree, that much maligned examination, the examiners have no notion of the lectures which the candidates have attended and hence in setting the papers they have to ask themselves what it is fair and reasonable to expect the candidate to know, rather than what courses of lectures the candidate has attended. I always maintain that it is a great education for any professor to have to act as external examiner for London. I know of nothing which brings home more forcibly the need for moderation in setting the standard of a final examination.

My pessimism results partly from watching how various universities have developed since the war, but also, and in a much more concrete way, from the Pink Book published by the Royal Society in 1945, on the needs of research and fundamental science after the war. Now such a book emanating from such an august body as the Royal Society will naturally carry considerable weight and there is already undoubted evidence that the University Grants Committee is being influenced by its suggestions and this is, of course, just as it should be. However, it is clear to me that the committee which advised the Royal Society in the preparation of that part of the report dealing with biology either failed to make any distinction between a research institution and a university or else were unaware of the existence of any university outside the Oxford-Cambridge-London triangle. They recommend the inclusion in the university curriculum of a variety of subjects all of the most painfully specialised nature. How they made their selection is to me a complete mystery. Thus, they suggested a Readership in Microbiology, whatever this may mean. I am assuming that since there is in brackets after the word Microbiology 'including general bacteriology', the term includes a study of the Protozoa and Protophyta. Now a Reader in a Redbrick University is a teacher—not merely a research worker. Where will be the students that such a Reader can teach?—

clearly they would have to be postgraduate. A student could not possibly understand such a composite subject until he had fully studied the groups of animals and plants included in it and seen their relation to the rest of the animal and plant kingdom. In Cambridge, of course, things are different for there will always be a sufficient supply of students taking the second part of the Tripos. But this is postgraduate ; the Honours degree is awarded on the first part. Now in the Red-brick Universities postgraduate students are very largely education students undergoing their teaching training and the remainder are research scholars. The former are, of course, fully occupied with their training, while the latter have all their own special interest on which they are carrying out their research. I should imagine that in a relatively large university such as Manchester, at a rough guess, a postgraduate student might turn up about once in fifteen years who had any interest in a course of instruction in such an unnatural subject as microbiology. Does this justify a Readership at a university? Would it not be much more economical and productive to devote the same expenditure to the establishment of a research fellowship at an appropriate institution? I am laying stress on these recent developments because I feel certain that many university teachers are becoming aware of the Royal Society's suggestions and, without stopping to consider how they can be fitted into the present scheme of teaching, are approving them. Thus to take the next suggestion : the need for improvement in the teaching of taxonomy. This has already produced a response, for at a meeting of the Linnean Society held early this year there was a lengthy and apparently most enthusiastic joint discussion on the subject. Now I have read carefully through the report of this meeting and cannot find that anyone suggested any real practical way in which the methods of taxonomy could be taught, beyond, of course, two or three lectures on the rules of the game. Again, does this justify the establishment of a University Readership? To my mind, the shocking thing about this suggestion is that the methods of classification are somehow to be dealt with separately from the general study of the living organism. I consider most emphatically that if a student graduates in zoology and does not understand the methods of taxonomy then he has been wrongly taught, but the way to put this right is not to include one more specialist course for the unfortunate student.

The last suggestion of the Committee deals with limnology which, as they are at pains to show, means freshwater biology. Now why pick on this? Why not salt water biology? What is at the back of their minds when the Committee pick this out of all the various subdivisions of biology? There is a pamphlet issued by the Royal Society in which the subdivisions of all the natural sciences are classified and it appears from this that there are more subdivisions of zoology than of any other science. Now why pick on these three—and only these three—specialist subjects out of all the others? It sounds incredible but the only things that these three subjects have in common is that they have an applied value. Have we descended so low that the recruitment of scientists to our university staffs is to be determined by the economic value of their subject? If this is not the explanation, then why stop at these three? Why not a Readership in palæozoology or experimental embryology or even straightforward embryology? These have no obvious economic application—is this then the reason why they were passed over? But, most sinister of all, why was experimental zoology passed over? Did it not occur to the Committee that despite all the developments of recent years towards the experimental rather than the morphological, there is not one single Chair of Experimental Zoology in the whole country? There is, in fact, one Readership and that is in my own University of Manchester. Is not the first step to take to see that this major development of zoology is adequately represented at professorial level before establishing more minor posts for these secondary specialisations?

What can all this mean? Simply this : that to the minds of those who sit in the Councils of the Royal Society, Experimental Zoology *is* Zoology. I would go further and say that in the minds of those who occupy Chairs, generally speaking, the same belief is held. Morphology and comparative anatomy are simply being pushed out of existence. I admit that at long last a greater interest is being taken now that zoologists realise that there is a functional side to morphology but the development and expansion of the specialised aspects of zoology has already gone too far.

The rise of experimental zoology is paralleled by the appearance of physical chemistry within the main subject of chemistry. This represented simply a new method of attack upon the whole problem of chemistry, and it led naturally and logically to the establishment of additional Chairs in Physical Chemistry. In zoology, the new science of experimental zoology similarly represented a new method of attack on the whole of zoology, but in this case instead of the establishment of Chairs or Readerships to function alongside the old-established Chairs of unqualified

zoology, the new outlook has usurped the seats of its progenitor—and all this, due partly, as I have explained, to historical chance, but largely resulting from the over-zealous enthusiasm of the adherents of the new cult. We have become completely unbalanced and with a slight push we shall topple over into a mass of cytogenetics and biophysics, of neurophysiology and even maybe of gerontology, and what will emerge from this mixture will certainly not be zoology!

And now, in conclusion have I anything concrete to suggest as a means of improving matters? Yes, I think that there are two main ways in which the teaching can be brought back to a more balanced state. First, from what I have said in connection with the Royal Society Pink Book, it is clear that I advocate the establishment of Chairs of Experimental Zoology or at least Readerships throughout the country to function alongside the normal Chairs of Zoology. I feel, moreover, that the greater part of my colleagues will be with me in this view. As regards my second suggestion, however, I am equally certain that I am in a very marked minority. I strongly advocate the disappearance of the Special Honours degree, or rather, I consider that, apart from some exceptional cases, students should be urged not to take the Special Honours degree but to take General Honours.

To deal with this matter fully would lead me too far afield and a few remarks must suffice. The special Honours degree is becoming an anachronism. In the old days it was expected of the Honours student that he should be *au fait* with all the latest developments in his subject. I think I have said sufficient to indicate that to-day such a thing is impossible. On the other hand, there has been established in most Redbrick Universities an excellent General Honours degree—a degree in no way inferior to the Special Honours degree. It is regarded by many as something new and I am afraid, as something inferior, but it is neither. The first part of the Tripos at Cambridge is a General Honours course and this certainly is not new and neither is it inferior. This is a degree which to my mind is intellectually sound. It gives the student a grounding in a variety of subjects and if it is properly taught of necessity it shows the interrelations of those subjects and it does not lead to that completely unintellectual isolation which results so often from the Special Honours degree. Moreover, it must be remembered that only a small proportion of our graduates continue as academic research workers: the majority go into the world in various capacities to earn their living as scientists. Now, for this, it is obvious that the General Honours degree course is far more suitable than the Special Honours course. One has only to think of a graduate going into entomology or agriculture to realise the greater value of a wide range of subjects.

If this were done, if we were all to follow the lead of Cambridge and make our examination for the Bachelor's degree a General Science degree then there would be no need for the disappearance of all the advanced specialised teaching which is already fully established but which I have criticised so adversely as being out of place in an undergraduate curriculum. It could be used as a postgraduate course corresponding to the second part of the Cambridge Tripos. With the abundance of money that is now available for scholarships, I think it is reasonable to anticipate that anyone doing sufficiently well in the Honours degree would be able to obtain a scholarship for the postgraduate year. And why should not a Master's degree be then awarded on such a year of directed specialised study? I consider that it would be a great improvement on our present method of awarding the Master's degree on a small piece of directed research.

SECTION E.—GEOGRAPHY

GEOGRAPHY AS A SOCIAL SCIENCE

WITH SPECIAL REFERENCE TO AFRICA

ADDRESS BY

RT. HON. THE LORD RENNELL OF RODD, K.B.E., C.B.

PRESIDENT OF THE SECTION

SOCIAL geography is concerned with the geographical environment of man as a *social* animal. I am, therefore, not going to be concerned with the origin of the human species or man as a prehistoric animal : the effects of geography in these fields are also obviously important and interesting. But what I am proposing to concern myself with to-day is the social geography of present-day man, which is, of course, inseparable from his history and his mental development.

Man as a social animal involves consideration of the abstract as much as the concrete side of his nature. Human society as an urban, agricultural, pastoral or hunting society has always been, and still is, affected by the geographical circumstances of these different modes of life, each of which has its own material as well as its related spiritual environment. It seems inescapable that the religions, customs and disciplines of human communities are, if not the end products, at any rate closely connected with geographical conditions. There are, no doubt, historical and anthropological reasons why Islam spread only where it did ; or why Hinduism grew in India but remained broadly confined to India. It is equally a matter of fact that the principal moment, in the dynamic sense, of Islam lay, and lies, in the steppes and deserts of the Middle East, from the Atlantic coast to the more arid parts of India. The vital force of Islam faded out in Europe when it crossed the Straits of Gibraltar and the Bosphorus : and having crossed the African Deserts it came to a dead end against the northern edge of the swamp and forest of Equatoria. The connection between the religion and thought of the Arab and the Desert is nowhere better described than in the opening chapters of Lawrence's *Seven Pillars of Wisdom*.

It is equally a matter of fact that Europe, and especially the northern half of Europe, produced the natural sciences and the great inventions, derived from them or leading to them, and also that the moment, using the word in the same sense, of Christianity is in Europe. Thoughts in this context can equally be applied and developed about North America ; many will suggest themselves to you without my having to elaborate them.

Assuming you agree, as I think you must, that Geography seems to govern man's material as well as his spiritual existence and development, I must direct your particular attention to the place of social geography in the field of thought and education. And this is one of those aspects of geography with which I am dealing as distinct, for instance, from physical or mathematical geography.

Before the great development of the natural sciences in the last century, higher thought and education were concerned with what may broadly be called the humanities, with theology and mathematics as, in a sense, derivatives of the humanities. The humanities themselves in the earliest days were, of course, deeply concerned with so much of natural science as could exist without the practice of exact measurement and experiment. But with the development of the natural sciences as exact departments of thought dealing with measurable things, a widening gulf, in modern times, has divided the natural scientist from the humanist. As natural scientists concerned themselves more and more with what was concrete, they came to disregard the humanities and arts as unmeasurable and abstract conceptions. They came indeed to distrust the realm of abstract thought, till only in quite modern times the greatest of them returned to philosophy and religion in order to break through the dead end they had met in their scientific progress. In this latter-day phase, mathematics seem to have become more and more inextricably mixed up with philosophy and things of the spirit. We are, for instance, told that Time is only a mathematical sign, a matter of direction. We are, however, also told that we live in an expanding universe which by definition

is a unidirectional development. Yet if the universe is expanding and unidirectional, that very conception requires that the universe shall have started to expand from a point—shall have started from creation. And so it is that the natural sciences, mathematics, religion and philosophy seem again to have met on a common field.

But while the natural sciences have developed towards things of the mind, the abstractions of thought which to-day we call the humanities have not developed on their side, as I see it, towards the natural sciences. In the academic world history, philosophy, economics, logic, theology continue to-day to be taught within a more circumscribed horizon, than is that of the natural scientist, though there still remains all too little of the humanities in scientific education and research. Since my own inclination has been towards the humanities I must be the first to admit that whatever may be the faults of the teaching of the natural sciences, there is even less of the teaching of natural sciences in the teaching of the humanities than vice versa and much less than there ought to be on both sides.

It has always seemed to me inconceivable how history and economics, for instance, could be taught divorced, as they so often are divorced, from geography. To me at any rate, history has never made any sense except within a geographical framework. Nor do I understand how comparative religion or anthropology can be studied without a deep foundation of social geography. If social geography is the science and study of man in his geographical environment, and if, as seems to me inescapable, geographical conditions affect the spiritual as well as the material circumstances of the human race, then I suggest that geography, and especially social geography, is the natural bridge between the humanities and the natural sciences, and that without that bridge there can be no understanding, but only accumulation of facts. I therefore suggest that geography, and particularly social geography, is the common ground to-day, as the classics were in mediaeval times, between the humanities and the natural sciences. Geography ought thus to find its place in the teaching of both schools.

At this point I am going to turn to Africa for examples of how social geography affects this submission. I shall raise certain issues to which I do not propose to provide the answers, even if I were able to do so. The British Association was founded for 'the Advancement of Science' : I therefore hope that by posing certain problems, I may help to stimulate research to advance science ; I hope at the same time to demonstrate outside our circle that social geography is the indispensable framework in which these problems must be studied and can alone find their answer.

What I suppose is conjured up in most of our minds by the name 'Africa' is that part of the continent of Africa lying south of the deserts which extend from the Atlantic to the Red Sea. Essentially it is that part of Africa which used to be, and is occasionally still, called the 'Dark Continent.' Somehow or other neither the Barbary States and Egypt, nor the Sahara and the Red Sea littoral are what leap to the mind when someone says 'Africa.' If you and I were to play the questions and answers game of the psychological investigators who help to select officers for commissions in the Armed Forces, or candidates for the Civil Service, and someone suddenly said 'Africa,' the 'normal' answer would, for example, be 'Livingstone' or 'Congo,' or 'Drums,' or 'Slavery' or 'Forest' but not 'Desert' or 'Camels' or 'Nile' or 'Sand.' Yet Africa north of the southern fringe of the Saharan deserts and steppes is larger in area than Africa south of that line.

There is, of course, a reason for these associations of ideas. The Barbary States and Egypt have been familiar to Europe for two millennia ; Africa south of the deserts has become familiar only during the last two generations. This is true from the points of view both of physical geography and social structure. While to-day we may know something, though still nothing like enough, of the physical geography of this Africa, we still know lamentably little about the people in it and practically nothing of their history. What we do know of their history is what we have been able to piece together from oral records collected when African society was already beginning to change rapidly under the impact of European penetration. In point of fact, the Africa of which I am now speaking is a continent without history, a fact which makes it all the more difficult to understand and study the whys and wherefores of its social structure. But without history we are driven to social geography for our only guide to the problems we find.

On the other hand the Africa of the Barbary States, and of Egypt, of the Sahara and even of the belt of Equatoria between the Desert and the Sown has a respectable historical background comparable to, and in some respects even better known than, the historical background of many parts of Europe.

Why has this happened ? The first reason, of course, is that Northern Africa has enjoyed the benefits of writing, and all that goes with it, in some form for two millennia. For more

than a thousand years Islam has been mainly responsible for this. Where Islam penetrated, history was recorded. But this in itself begs the major question. Why in fifteen hundred years did Islam, broadly speaking, only penetrate as far as Equatoria and not permeate also what might seem to have been the fruitful human fields of the West African and Bantu peoples? Why did Islam win the Fulani of Equatoria after crossing the Sahara and leave Ashanti untouched? Why, with the apparently less difficult country of the Upper Nile basin to cross, did Islam never touch the Masai, yet win the pastoral Somali?

When Europeans came into the dark part of the African continent some 60 to 70 years ago they found an enormous land area with, not a dense population, but with a much denser population than our Elizabethan seamen found in North America or later explorers found in Australia. In this vast area and large population not one single indigenous community from the Ashanti to the Zulu possessed script, used a plough, knew the wheel, or practised any form of architecture in the generally accepted sense of the word. Yet many of the people had apparently indigenous music, sculpture, handicrafts and, in many cases, quite evolved though intensely local systems of government.

I am not going to enter into the problems of culture contacts or spontaneous cultural development. I will confine myself to noting that while some aspects of culture seem to have developed in Dark Africa, those most essential to material and collective civilisation not only did not develop but do not even seem to have been copied during the three millennia during which such contacts are known to have existed and could have developed, Why did the wheel and plough, so useful to man and so well known in the Mediterranean, not even reach Lake Victoria before they were introduced by Europeans within our fathers' lifetime? Why was writing used only by the Semitic immigrants on the East coast of Africa and never practised, initiated, or copied by, say, the Bantu people? So far as I know, the negro people of Africa never even developed an ideographic system of their own. I have my own ideas and no doubt you have yours about the reasons for this: the social geographer alone can clarify our thinking on the subject without being accused of political and racial bias, and may draw the appropriate conclusions.

Physical difficulties of communication do not in my view affect the problem at all. The Sahara was, of course, not a barrier but a means of communication with its caravan routes analogous to maritime trade routes in enclosed seas or along coasts. The contacts provided by these routes indeed led to the creation of the great imperial domains of Equatoria which developed south of the Sahara on at least as imposing a scale as the Empire of Morocco, the Kingdom of Algiers and the domains of Middle and Upper Egypt. The Songhrai and Melle Empires of the Middle Niger, the Kingdoms of Bornu and Axum developed, left records, and made monuments. But all this stopped short well north of the Equator: well north of the domain of the purely negro peoples. Central and Southern Africa have nothing of the sort to show. Yet trade routes of most respectable antiquity existed throughout Africa, producing what? The Niger, the Benue, the Ubangi and Shari, the Nile Valley, Ethiopia, and the Red Sea coast provided ways of hoary antiquity through or around the forest belt. Ephemeral kingdoms and tribal confederations without progress beyond a generation's span, without prosperity, and without material culture, were the rule south of this northern Equatorial belt. Somaliland had its contact for centuries with Arabia: the Somali language seems never to have been reduced to writing. There is no known trace of Himyaritic script in Eastern Africa. Islam stopped dead at the Tana river until quite modern times. Axum never civilised Galla or Uganda. Egyptians, Greeks and Carthaginians explored the African coasts, probably also the interior in parts; then came the Dhows of south Arabia, the Persian Gulf and Malabar to make settlements all along the coast of Africa; and in the Middle Ages came the Portuguese. But the Africans would take nothing from these contacts. They assimilated nothing until Europe from 1890 onwards carved up Africa by force, knowing nothing about its people or its geography and evidently caring less. Then, and only then, all of a sudden, among many millions of people still in a stone age period of development a ferment was thrown and a yeast began to pullulate.

The progress of civilisation in Europe and Asia governed by geographical configuration, climatic areas, and cognate ethnic grouping usually, but not necessarily always, has manifested itself in the creation of nations or communities of common governments. Economic considerations and spiritual factors themselves frequently dependent on, or provoked by, geographical consideration have played their parts, but have not apparently been the decisive factors. We all know this without my having to develop the subject by giving examples. These entities, at any rate the more important, numerically or materially or spiritually, have lasted for appreciable periods, and some still last. So did those

Northern African ones to which I have referred. But we know of no similar examples in Dark Africa. If there were some knowledge of them, it is lost to history, and they have disappeared leaving no trace. We have no material evidence of indigenous civilisations in Africa like the Mayan or Incan; we have no ruined cities of the Silk Road on the trade routes of inner Africa.

By the time Europe came to Dark Africa 70 years ago, in the haphazard way in which it did, there were no large civilisations or even units of common administration, with a few doubtful and local exceptions like Ashanti, the Zulu organisation, the Somali, and the Masai. Moreover, the ethnic groupings had ill-defined geographical boundaries except in the case of the Somali. As a matter of fact, from the ethnic point of view Africa contains few well-defined areas. Indeed the Horn of Africa, with its virtually homogeneous Somali population, is one of the very few well-defined areas of the social geographer. Elsewhere one area and one people merges into the next area and the next people with quite imperceptible boundaries, or one people is superimposed on another people again without clear edges. I wonder what is the reason for, on the one hand, the intense fractionalisation of certain closely inhabited areas into small communities with different languages but in the same sort of geographical area, as in Southern and South Eastern Nigeria, or on the other hand, for the existence of large groups of people of the same races in very varying areas, or, finally, for the juxtaposition of different races in compact areas like the highlands of East Africa or the Congo basin. In such generalisations I am bound, I know, to be picked up by experts on any particular subject, but I am trying to keep the canvas of my picture on broad lines because I want the social geographers to keep a broad outlook and seek to give broad answers.

Into this ill-defined land mass of merging landscape and people came European traders, with, for instance, the factories of many nations on the Guinea Coast, to some points on the east and west coasts further south and later to southern Africa. But until about a century ago when the Missionary phase which coincided with the great trade development of the Victorian Era in England and Western Europe, these Europeans had stayed on the coasts. Then all of a sudden everything started happening very quickly. Ostensibly there was the missionary zeal of Christian proselytising. Ostensibly there was the feeling—very strong in this country—that it was the duty of our people to carry justice, peace and civilisation to the backward people of Africa. Ostensibly there was the desire to abolish slave trading and slavery. We are told by historians and politicians that the need for trade, or the desire to trade, was the real reason. I doubt myself whether if this was a real reason it was the sole reason. So far as Africa was concerned there was neither the urge nor the necessity nor the opportunity for trade which could, or, in fact did, compare with trade with India and the Far East. The total value of European trade with Africa from, say, 1884 to 1914—30 years—was a small part only of Europe's trade with the Middle or the Far East. To-day some social philosophers say that the colonisation of Africa with its primitive and readily conquerable people was the result of an urge for power. It is very doubtful that that was the urge in 1890.

My own view is that you must look for the explanation of Europe's African adventure from 1880 to 1910 rather in the abstract than in the material incentives. At this point it is relevant to observe that no one has yet succeeded in answering the very simple question :—Why did Europe go to Africa and what have the various European countries concerned been trying to achieve there for the last fifty years. This is the question which prompted the inquiry conducted by Lord Hailey, and which, still in progress, first culminated in his Survey of Africa. But in all his years of research he is still unable to find the answer to the question : What are European nations trying to do in Africa and how are they trying to do it? In point of fact he has found a different answer in every part of Africa administered by Europe and that in almost every part a different method is being used with different objectives. If in certain respects and in certain areas the purposes and objectives are clearer than they were, they remain diverse, and are, broadly speaking, as obscure as they were fifty years ago ; if any material things are regarded.

It is this background or perhaps lack of background which has made the modern complication and mess which is Africa. Never I suppose has so much money been spent and so much energy displayed by so many European nations with so little clear idea of why they were doing it. The plan and purpose of European expansion in India, Malaysia, Indonesia, even North America were and are clear. In Africa they were and are glaringly haphazard and for two generations have apparently seemed purposeless.

Let us now consider one or two present difficulties which have been engendered by this state of affairs. In West Africa we have an example of ribbon development along the arterial road of the sea coast. We have strips of frequently rectangular colonies running up into the interior on lines of longitude, or along rivers as in the case of the Gambia,

which has been described as a vermiform colony surrounded by politics, in the development of which we bartered parts of the territory away to the French against Newfoundland Fishery Rights. In the Congo we find a vast area with a minuscule door on the sea and cut off from access to the Nile since the Lado Enclave was surrendered. In French Equatorial Africa we have a miscellaneous collection of territories ranging from the truly Saharan Chad Territories to a part of the Congo Swamp, devoid as a whole of internal communications except by rivers where there are perennial rivers and provided with an even smaller and less accessible door on the Atlantic, cheek by jowl with the Belgian door which is not used by the French and vice versa. We have several small Spanish and Portuguese colonies like plots of land on a road frontage displaying a front door with no house behind. On the east coast we have a compact mass of British administered land artificially divided into several administrations which are largely run separately and are only just on visiting terms with each other. Further south we have another group of three British territories also kept rigidly apart from each other, thanks to the strenuous efforts of the Colonial Office, with no access to the outer world except by using a Portuguese front door. At the bottom of Africa we have a great self-governing Dominion of the Commonwealth containing islands of colonial territory which the Union of South Africa is not allowed to administer. And finally we have the two Portuguese colonies of South-East and South-West Africa with no land contact between them.

You know something of how all this happened. But that it has happened is not particularly creditable to Western Europe as a whole. That all this should continue to be is simply disgraceful. It is here that the social geographer can and must play his part in the broad plans which are necessary to remedy this disorder.

But not only here. Up to a few years ago one underlying theory, at any rate in the British West African colonies, was that the territories were to be developed solely for the benefit of the African inhabitants. In Eastern Africa this theory also obtained with reservations regarding the status, rights, and future of white colonisation. Certain colonies administered by other European powers were frankly described by all parties as ' Colonies d'Exploitation ' where the European was frankly there only for the purpose of developing the resources of the territory for his and his home country's benefit. This did not mean that in those colonies administration of the African was not good or enlightened but the motive was not as allegedly altruistic as in our West African domains. The difference between these standpoints has in recent years become less marked in the process of each side tending towards the other consciously or unconsciously. Within the last year or so our own government for the very laudable purpose of increasing our own and other European countries' food supplies has frankly gone over to exploitation in the Ground Nuts Scheme of Tanganyika and in other enterprises of the Colonial Development organisation. While I am far from criticising this change of attitude, especially in our present government, I must point out how much more work there is before the social geographer in helping to adapt such schemes of exploitation as are being furthered, for instance, by the Overseas Food Corporation to the Trusteeship principle. It requires no imagination to see here the vista of useful work for the social geographer in this field. Nor does it need saying that here again he and he alone can provide the bridge between the economists of food production and colonial finance, the scientific agriculturalist and botanical research specialist, the transport manager and the township planner, and finally the administrator and the civil servant in the Colonial Office.

I have not in this address attempted to do more than to ramble round a vast subject. I have tried to touch on certain problems of research open to the social geographer in the recent past of Africa as well as in the present phase. Let me in conclusion express one very definite hope. In general education a large modicum of geography should be included in all curricula for school and higher certificates and for university matriculation. In honours courses both on the humanities side and in the natural sciences I would like to see Social Geography included to remind candidates that in all their work man counts first, and that by a perception of his environment and conditions the isolation of what has been called the academic standpoint can be, and ought to be, broken down. I believe that neither the humanities nor the natural sciences can do without each other and that the bridge that was a classical education can to-day be replaced by geography and Geography alone. For Geography is both the science and the art which deals with mankind on the earth on which we live. Finally for our own good name, the social geographer must be called in to play his very large part in adapting our changing conceptions of African administration and in seeking to rationalise the mess which Western European nations, including we ourselves, have made in the African Continent.

SECTION F.—ECONOMICS

THE PRICE SYSTEM

ADDRESS BY
SIR HUBERT HENDERSON
PRESIDENT OF THE SECTION

A YEAR ago, my predecessor in my present rôle, Professor Dennis Robertson, devoted most of his address to a review of the controversy which was then active about the potentialities of economic planning. I had made my own contribution to that controversy, the Rede lecture which I gave in Cambridge and which I was moved to write, partly by what seemed to me the incoherence of the planning ideology which was prevalent, and partly by the suspicion that planning appealed to many as having the properties of a magic charm which would enable us, not to solve, but to shirk our problems. Since then the ideologues of planning have remained mostly on the defensive, while their opponents, marching under the banner of a return to the price system, have launched a general assault. I had better confess at once that this revivalist ideology seems to me marked by the same defects which repelled me in planning ideology, that is to say, incoherence, and wishful thinking. The phrase 'the price system' is bandied about as though its meaning were self-evident, and as though it too had the properties of a magic charm. I propose in this address to examine it closely; and in order to minimise the risk of misunderstanding, I begin with a recital of first principles.

In its most general sense the price system is an inevitable outcome of the use of money. Wherever goods and services are bought and sold for money, there must be prices; and these prices must always exert a powerful and pervasive influence. Price provides the principal criterion for resolving every problem of economic choice, both the problems of an individual arranging the distribition of his personal expenditure, and those of a manufacturer in organising his processes of production. Rationing and allocation schemes may narrow the area of choice, both for the consumer and for the producer; but where choice exists it is exercised by constant, if often tacit reference to the price criterion. In fact, the problems of choice which arise in ordinary private and business life, even in a highly controlled society, are very numerous; though they are nothing like as numerous as the problems which *might* arise, if they were not settled decisively, by a subconscious appeal to the price criterion, without, so to speak, coming into court. We do not actually have to worry our heads about replacing our china dinner service by more durable gold plate. Nor does a publisher have to spend a moment in considering whether to print his books on paper or on parchment. But, if there were no such things as prices, there would be an infinitude of such questions which someone would have to settle somehow.

The influence of the price system in this sense is far more pervasive than that of the profit motive. A private trader or manufacturer, operating in a highly competitive market may be more vividly conscious of price considerations and more quickly responsive to them than the conductors of a publicly owned industry, but the latter do not and cannot leave them out of account. Their actions may diverge from those suggested by the price criterion, either from inattention or inertia, or because of decisions made deliberately for good reasons or bad. But in all their decisions, the price criterion is an essential factor. It is the needle which points out the course to follow where there is no reason to deviate from it. And here too the questions which call for deliberation are only a small fraction of those which escape attention because the answer given by the price criterion is categorical and obvious.

This then is the first proposition which I wish to emphasise: that even when our economic activities are subject to a multitude of physical controls, and even if most of our major industries were to be nationalised, the influence of the configuration of prices which exists at any time remains strong, far-reaching and fundamental. It is important, therefore, that this influence should be a healthy one, that the configuration of prices should be such as to pull in directions which accord with

the public interest. The price criterion may work very badly, as we have plentiful present reasons to know, if the relations between different prices are, to use a common phrase, distorted. We want price relations that are right, so far as that object is attainable. Unquestionably, this desideratum was unduly neglected in our governmental policy a year or two ago. Indeed there seemed then to prevail in Ministerial circles a curious unwillingness to notice the influence of prices, an averting of the eyes which was almost prudish, or, perhaps it would be better to say, reminiscent of the mental habit of Mr. Podsnap: 'the forces of the price system are un-socialist; therefore, we refuse to acknowledge their existence.' They exist none the less for that; and it is always important to have them working for, and not against, the public good.

Here, however, we must be careful not to beg a major question. In the matter of price relations, as in many others, it is easier to be sure that certain things are wrong than to know at all precisely what is right. In times of large-scale economic maladjustment, is there really such a thing as a right price for any commodity or service or factor of production; or are there merely widely separated limits within which the price should lie? If there is such a thing as a right price, how is it to be determined and established?

At this stage, I think I can most conveniently develop my argument by considering the answer that would be given to these questions by those whom I call for convenience, the ideologues of the price mechanism. In broad outline, their answer would be as follows: Trust to the forces of a free market, operating under conditions of effective competition, and with the minimum of interference by the State. The right price will then be secured by the interplay of demand and supply on price, and of price on demand and supply. This will be for any particular commodity the price at which demand and supply will be in equilibrium; and the establishment of equilibrium prices throughout the economic system will carry with it the corollary that the relative prices of different things will be right, in the sense that their pull will be in the directions that are needed for the most efficient use of the productive resources of society. Something of this sort is what is usually meant by those who call to-day for the restoration of the price system.

I have stated this view, of course, in a crude and summary form. Perhaps nobody would associate himself with it without adding various qualifications or reservations. All would concede that due allowance must be made for the so-called 'wastes of competition.' Some regard these wastes as comparatively unimportant, others as extremely important; and differences of judgment upon this matter form one element in controversies about nationalisation versus private enterprise. Again most economists would admit or affirm that large inequalities of income or wealth impair the claims that can be made for the results of a freely working economy; though those whom I call price system ideologues tend to repudiate the inference that this may justify such expedients as controls or rationing schemes, and to insist that the appropriate remedy is to do more than is done already to abate the inequalities of wealth by redistributive fiscal measures. I say no more about these qualifications or the issues which they raise, but pass to a large reservation which brings us much nearer to the questions which I wish to examine.

The strongest advocates of a free economy are nowadays increasingly inclined to concede that, before it can be expected to work well, a prior condition must first be satisfied. A rough adjustment must be established between aggregate supply and aggregate demand; otherwise a freely working economy may result in inflation, if demand is overstrong, or in a prolonged *malaise* of depression and unemployment if it is too weak. Now this is a considerable admission. First it implies that if aggregate demand and aggregate supply are out of balance, or at any rate, if aggregate demand is greatly in excess of aggregate supply, controls and allocation schemes may be needed after all. Second, it implies that one of the reasons why they may be needed is that otherwise the prices brought about by a freely working economy may be far from right. Third, it implies that the necessary equilibrium between aggregate demand and aggregate supply cannot itself be ensured by trusting to the automatic responses of a free economy. This task, it is recognised, can only be discharged by deliberate policy, perhaps taking the form of a budget surplus in some conditions and a budget deficit in others, perhaps extending to such matters as the rate of interest and the stimulation or restraint of capital investment; in any case deliberate State policy, which is thus assigned a positive rôle of key importance in the economic system. This takes us far from *laissez-faire*, a fact which most exponents of the views I am examining are eager to proclaim and to stress; for although eulogies of the price system and a free economy are again in fashion, the *laissez-faire* philosophy is not.

Without forgetting the qualifications mentioned earlier, we may therefore restate as follows the central prescription of price-system ideology: Let the State attend to the

balance between aggregate demand and aggregate supply. Let it concentrate on that one all-important equation, and leave to the free play of impersonal economic forces all the detailed adjustments of the economic system. Let the State see to it that global equilibrium is established, and it need not worry about particular disequilibria. It can then leave the producer free to produce what he chooses as he chooses, in response to the inducements and deterrents of the price system; and it can restore a similar freedom of choice to the consumer, including the choice between home-produced and imported goods.

I have cast this restatement in a topical form in which it makes a wide and growing appeal, and to judge from recent publications is especially attractive to economists. From different angles and with important individual variations Professor Jewkes, Mr. Harrod, Professor Meade and many others in this country and abroad, can be observed converging on the formula: 'Equate aggregate demand to aggregate supply and set the price system free.' Nor is this formula propounded on purely practical grounds. It is suggested that it represents the fruits of the latest developments in abstract economic thought, the distillation of the genius of Lord Keynes, a profoundly thought out synthesis of new facts and the wisdom of the ages, appropriate to the conditions of our time. We badly need such a synthesis, I agree; but for my part I cannot find it in this formula.

Up to a point, undoubtedly, it seems well adapted to our present practical requirements in Great Britain. In my opinion at any rate, it is vitally important to eliminate the excess of overall demand in our internal economy. Such an excess, if long-continued, depletes the stocks of finished commodities, raw materials, components and spare parts, which represent the indispensable lubricant of a smoothly working economic system. It increases the difficulty of making an adequate volume of goods available for export. It entails an inflationary trend of prices and wage rates, and a constant danger that the momentum of this trend may at any time become uncontrollable. I have no doubt, therefore, as to the paramount practical importance of eliminating the excess of aggregate demand as speedily as possible. It would be most rash, I would add, to relax our efforts towards this end, until we are quite sure that it has been achieved. All this, however, leaves unanswered the pertinent questions why this excess of aggregate demand should have arisen and why it should be so very hard to get rid of it.

To continue the main argument, I hope and believe that the elimination of the general inflationary trend in our economy would carry with it the substantial elimination of many particular maladjustments, and would thus enable us to dispense with many of the controls that irk us to-day, and to simplify others. But would it enable us to remove them all? I do not believe it. On the contrary, I am convinced that controls, that is to say, direct, physical controls, working otherwise than through the price system, will remain indispensable in some important sections of our economy. I have in mind, in particular, the regulation of long-term capital expenditure, which I expect will be desirable for a fairly considerable time, and the regulation of imports which I am certain will be necessary for a much longer time.

My dissent from the ideology I am examining goes much deeper than a distaste for what I am sure all sensible well-informed persons would agree with me in regarding as its over-sweeping claims in matters of practical policy. Its logical foundations seem to me unsound. The main idea on which it rests is the concept of an equilibrium price to be brought about by the forces of supply and demand. In times of large-scale economic maladjustment, this concept of an equilibrium price is, I submit, ambiguous. The theory of value comprises two parts, a short-term part and a long-term part, though as Alfred Marshall was careful to warn us 'of course, there is no hard and sharp line of division between long and short periods.' In the short run, the supply in any market may be taken as a more or less fixed quantity; and the equilibrium price is that which will so curtail an excessive demand, or so stimulate a deficient one, as to match the immediately available supply. In the long run, the supply of most things can be radically altered; and the equilibrium price is that which will evoke a rate of supply sufficient to meet the demand which will be forthcoming at that price. For a particular commodity, accordingly, the long-run equilibrium price corresponds to the cost of producing it, including in that term a fair profit margin.

Now in ordinary times, when the economic system has not been subjected to any recent large disturbance, the short-term and long-term equilibrium prices of most things are seldom far apart; and any small difference between them resulting from some small maladjustment between supply and demand serves as an effective and comparatively unobjectionable means of correcting that maladjustment. If, for example, the demand for some particular commodity or material expands so as to outrun the current rate of production, the price tends to rise, production becomes more than usually profitable, and the rate of production is increased until it becomes sufficient to meet the enlarged

demand. For this purpose, a very moderate rise of price will usually suffice ; and a very moderate rise is all that usually occurs when times are what I have called ordinary, though there may be important exceptions even then. These are the conditions in which the price mechanism in a free economy works efficiently.

The story is apt to be very different when the maladjustments to be corrected are very large. If it is a case of a large excess of demand over supply, the short-term equilibrium price may be very high indeed, much higher than is useful in stimulating additional production. For an exorbitant price does not stimulate production appreciably more than a good price ; it frequently stimulates it less. Indeed it is a well-established paradox that an excessive price sometimes leads to a decline in output, because many classes of producers are disposed to work less hard when an accustomed income can be earned with less exertion. On the other hand, the disadvantages of an exorbitant price, or in more popular language, a profiteering price, may be very great.

Not that I wish to suggest that in the absence of controls a large excess of demand over supply will always lead to a price that is grossly in excess of costs of production. The actual price in such conditions will depend largely on the type of market in which the commodity is bought and sold. It will come near to the short-term equilibrium price for those things which are sold on organised exchanges, as are normally most staple agricultural commodities. But for goods which are produced to fulfil orders, as are most industrial products, the prices at which the orders are placed usually represent some sort of compromise between those which might result from a free auction on the one hand and the costs of production on the other ; a compromise in other words between the short-term and the long-term equilibrium prices. The character of the compromise varies from one type of commodity to another. It is useful to note in passing that the deviation of price from the norm set by costs of production is usually least when the price is fixed by the unilateral decision of the producer, as it is for branded goods, that is to say where competition is most imperfect. It is not monopoly but competition which forces up prices most in conditions of shortage.

It is a mistake, therefore, to suppose that in such conditions the theoretical short-term equilibrium price is either what we want, or what we normally get in a free economy; or that relative prices would be 'right' if the State did not interfere with them by controls and subsidies. The paradox that the prices of secondhand motor cars are often a good deal higher than the prices of new cars of the same makes can be observed to-day in the United States, no less than in Great Britain. This matters little, but it illustrates the anomalies that are apt to occur in price relations when shortages are widespread. Some of these anomalies do matter ; and it is important to limit their growth. Unless we are to go out of our way to force up the less volatile prices to profiteering heights, this means that we must keep down the more volatile by appropriate restraints. Prices fail, in these circumstances, to discharge the function of lopping-off excess demand ; and problems of allocation must be dealt with by other means or left unsolved.

It is true that shortages or surpluses are apt to be most widespread, and the consequential anomalies most serious, when there is a large maladjustment between aggregate demand and aggregate supply. But it is not true that the former disequilibria are always a mere by-product of the latter. They may sometimes have a common origin, as in the great economic disturbance caused by a major war; they may sometimes arise independently ; or the relation between cause and effect may be the other way round, for sometimes particular maladjustments may play a big part, as I believe they do now, in causing or maintaining a maladjustment between aggregate supply and aggregate demand. However this may be, particular maladjustments of large magnitude and crucial importance may remain, after global equilibrium has been restored. Wherever such maladjustments exist, the short-term equilibrium price may diverge widely from the long-term equilibrium price ; and real difficulties and problems may arise, for which the ordinary price mechanism affords no adequate solution.

These are the generalities which seem to be relevant. I am conscious that they come very near to being platitudes which it should not be necessary to labour at such length. I have felt impelled to stress them by the fact that they are so completely, and sometimes it seems so perversely, ignored in current price system ideology. I pass now to consider their bearing on the most formidable of all our national economic problems—the large and persistent deficit in our balance of international payments.

Is there really any reasonable prospect that the restoration of balance between aggregate demand and aggregate supply in our internal economy would enable us to entrust our external economy to the price mechanism, that is to say, to remove restrictions upon imports, including imports from dollar or other hard currency sources? Is this even conceivable, so long as the prices of the foodstuffs and raw materials which we have to import are as high

as they are to-day? The question is one which we are in a fair position to judge; for though we have not yet eliminated the excess of aggregate demand in our internal economy, we are not, I hope, very far now from doing so. The progress we have made in this matter has not, however, brought us within sight of closing the deficit in our balance of external payments. Even the target laid down in the Economic Survey for 1948 went no further than a reduction of this deficit to £250 millions in the present year; and in the light of what happened since, there is little chance that that target will be hit.

We are running a formidable deficit in this vital sector of our economy despite the fact that our total volume of imports is held down by means of an austere programme of import restrictions to about 80 per cent. of the pre-war level, and despite the fact that our commodity exports are considerably larger in volume than before the war, let us say by about one quarter. Additional exports normally require additional imports of raw materials. Accordingly, the volume of imports available to satisfy the needs of our resident population is probably appreciably less than 80 per cent. of the pre-war volume, although this population is more numerous than it was. On the other hand, our consumption of goods and services as a whole, though its exact rate is a matter of some abstruse controversy, cannot reasonably be put much lower than before the war, at any rate when capital goods are included, as it is right to include them for the present argument. So we have the contrast: consumption of imported goods less than 80 per cent. of pre-war, total consumption about 100 per cent. of pre-war.

If the consuming public, together with manufacturers and traders, were free to choose between home-produced and imported goods, there is no reason to suppose that imported goods would represent a smaller fraction of their total purchases than formerly. It is true that in the absence of subsidies, imported goods would have risen more in price. Against this, however, must be set the re-distribution of net income in favour of the lower income-groups, who spend a smaller part of their income than others on services, and a larger part on commodities from overseas. If, therefore, import restrictions were removed, it would seem only reasonable to expect that the volume of relevant imports would return from less than 80 per cent. to about 100 per cent. of the pre-war level, an increase of more than a quarter. At present prices, which might of course be increased by additional purchases, this would add over £400 millions to our national import-bill.

How would this result be affected by the definite removal of every vestige of inflation? This might serve to reduce our aggregate consumption somewhat, and the demand for imports correspondingly. Conceivably, our aggregate consumption may have to be reduced, failing a sufficient further increase in output. But no one, I imagine, would suggest, least of all the critics of austerity, that our aggregate consumption of goods and services may have to be reduced by 20 per cent. or more. This is the magnitude of the reduction that would be needed, if the removal of import restrictions were not to result in increased expenditure on imported goods.

It may be hoped that the elimination of excess demand will also help to increase our exports. That is one of the many reasons why it is so important to eliminate this excess. But we need a large increase in our export receipts in order to close the existing deficit in our balance of payments, which Marshall Aid is not enough to cover; and when Marshall aid runs out we shall need in addition all the reduction in import prices for which we can fairly hope. In the meantime, we are in no position to contemplate a largely increased expenditure on imports. We have to keep our imports down and get our exports up as well. I cannot gainsay anyone who complains that once again I am labouring the obvious. I observe only that this disposes of the doctrine that if we re-establish global equilibrium we can leave the balance of payments to take care of itself.

The locker of price system ideology contains, it is true, another shot. This is the idea that disequilibria in the balance of payments can always be corrected by variations in foreign exchange rates, though opinions differ widely as to how this idea should be applied. Professor Jewkes, in his *Ordeal by Planning*, argues that the level of exchange-rates should be left to the free play of supply and demand in foreign exchange markets. Indeed, he seems to regard the fixing of even tentative exchange parities as constituting in itself an illegitimate interference with the price mechanism.[1]

[1] 'What would have happened in the free economy? The State would have confined itself to its legitimate role of restricting the volume of money sufficiently to prevent domestic inflation. Exports would have been stimulated because that would have been the only outlet for goods. The cramping effect upon industry of physical controls would have been avoided. No export targets would have been fixed, exports would have been left to find their own level. The long-period exchange rate would have been left to determine itself. A deficit in the balance of payments would have been met by a fall in the exchange rate, thus increasing exports and reducing imports. If the nation was living at a level beyond its means, the fact would have been immediately signalled to all and the increase in domestic prices would have pressed down the standard of living to what was possible.' Jewkes, *Ordeal by Planning*, p. 234.

In this, however, I think he is exceptional; and a more prevalent view is that exchange parities should be altered from time to time as a means of correcting balance of payments disequilibria. Those who hold this view are not all of one mind as to whether the pound sterling should be devalued in Great Britain at the present time. Some appear to advocate this course, or at any rate did so about a year ago; for on this matter minds not only differ but are apt to change. Professor Meade, in his inaugural lecture at the London School of Economics, expressly disclaims this proposition, and declares himself uncertain whether devaluation will eventually be needed. But he joins with the others in insisting that devaluation, in contradistinction to import restrictions, is the right remedy for our balance of payments difficulties, if they should prove obstinate. On the other hand, Professor Hawtrey, whom I think it is fair to class as a price system ideologue, though of a highly individual type, urges the opposite course, the raising of our exchange-rate with the dollar, on the ground that the pound is at present under-valued by reference to relative price-levels, and that this gives us bad terms of trade and acts as an inflationary force.

I cannot attempt in this address a full examination of these diverse views. But I point to their diversity to illustrate my central theme. The ardent advocacy of exchange depreciation in the abstract, in which most price-system ideologues indulge, is attributable to the pivotal rôle which they assign to the concept of equilibrium price. There *must* be, they believe, some equilibrium rate of exchange which would equate the supply of and the demand for dollars. I reply that when our import-export balance is so far from adjustment, there is a huge divergence between the theoretical short-term equilibrium rate and the theoretical long-term rate. The former is that at which the demand for foreign exchange would be in balance with the supply accruing from business transactions. The relevant long-term norm for the exchange-rate between two currencies, corresponding to the cost of production as the long-term norm for the price of a commodity, is, to use the phrase coined in the last post-war period by Professor Cassel, their purchasing-power parity; not, of course, that that is likely to remain constant in unstable times any more than the cost of producing a commodity remains constant.

It is to this norm that Professor Hawtrey appeals in maintaining that sterling is too low relatively to the dollar. I am not quite sure that he is right in maintaining this; subsidised prices and changes in relative productivity make the relevant price-level calculations a treacherous bog. But he may be right, or the trend of relative costs may soon make him right. If so, I infer that our exchange-rate is about where it ought to be. For the price prescription which I offer for conditions of serious maladjustment is that the price should deviate from the long-term norm in the direction of the short-term equilibrium price, but only by a narrow angle.

It is important that the angle should be small. Just as an exorbitant price is seldom more effective than a good price in stimulating the output of a commodity, and may sometimes even lower it, so an exchange-rate which is far below purchasing-power parity is seldom more effective than one which is only slightly below this norm in improving the balance of payments of a country in deficit, and may even worsen it. It would be foolish therefore, and possibly disastrous, to try to make actual rates of exchange correspond to the short-term equilibrium rates, when these would be far below current purchasing-power parities. This is not a matter of *a priori* dogmatism. It is the principal lesson which was taught, even if we have failed to learn it, by the runaway currency inflations on the Continent of Europe in the 1920's. A marked and almost invariable feature of these inflations was that exchange depreciation in the country concerned moved far ahead of the rise in internal prices, so that the deterrent to imports and the stimulus to exports were as strong as any price system ideologue could possibly desire. Yet the balance of payments was normally worsened, because the effect on the terms of trade outweighed the effect on the relative volumes of imports and exports.

The inflationary process was therefore cumulative. The rise in internal prices, though never catching up with the external depreciation, at least until the final stages, was always hurrying after it. It proved difficult to balance budgets in such conditions; and the process continued until eventually it was ended, whether before or after it had culminated in a complete *dégringolade*, by applying what came to be recognised as the indispensable remedy. This was to hold the foreign exchange-rates firmly for a period, by means of foreign credits or the free use of the country's own gold reserves at a level in the neighbourhood of the purchasing-power parity. So only could the breathing space be secured in which any other measures that might be needed for stabilisation could take effect.

These things happened in the days of unrestricted foreign exchange markets, when individuals were free to put their money abroad. This freedom, by the way, was

regarded then, and indeed right up to 1939, as an essential feature of a free economy. Now that capital movements are tightly controlled in most countries, it is unlikely that an inflationary movement would conform to the model of the 1920's in all respects. On the essential point, however, of the capacity of exchange depreciation to improve a country's balance of payments, this experience is extremely pertinent. If contemporary experience is preferred, the large and rapid increase in French prices which followed the devaluation of the franc in January 1948 is equally apposite. British economists, I suggest, would do better to heed these lessons than to bandy calculations in terms of elasticities conceived as quasi-constant ratios, capable of measurement. In effect, all such calculations beg the crucial questions at issue, taking for granted first that a country can push exchange depreciation to any degree desired without affecting its internal price-level, and second that the effect on the balance of payments, assuming this to be favourable, will increase without limit with the degree of the depreciation.

I submit, then, that for correcting a huge maladjustment in the balance of payments, such as still confronts Great Britain, counter-inflationary financial measures, though helpful, cannot suffice ; and that exchange-rate variations might be harmful. It is essential to keep down the volume of our import purchases as effectively as we now do by means of import restrictions. And not only to keep down their total volume, but more particularly that part of them that comes from what we call hard-currency sources. The principle of non-discrimination does not fit a world in which the whole international balance of payments has been upset.

There remains another aspect of the problem to which I should refer. Might not the necessary limitation of our import expenditure be secured by means more conformable, as the phrase goes, to the price mechanism than quantitative import regulation ; for example, by high tariffs or by the auctioning of import licences, as Professor Meade persistently suggests ? My answer is, where we are free to choose, that that method should be chosen which will secure its object most simply and most effectively. For some commodities, duties are unquestionably the most appropriate form of import limitation, notably for tobacco where the objects are mixed, and the indirect saving of dollars through the raising of revenue may well predominate over the direct saving accruing from a cut in purchases. But many of our import restrictions are prohibitions, complete or nearly so, at least on imports from particular countries. Nothing would be gained, not even a saving of administrative costs, by replacing these prohibitions by duties designed to be prohibitive. Here the quantitative method is simpler, more straightforward and more certainly effective. For other commodities it may be important to avoid raising prices to the home consumer. Again, a large part of our imports is purchased at present directly by the State, and here manifestly it is impossible to evade the quantitative question, how much the State should buy.

The principle that I have suggested applies, of course, more widely. Wherever the need for effective regulation is made out, the question of the best method to employ should be settled on merits, in the light of the relevant circumstances, and not by ideological prepossessions, either for the price system or against it. Quantitative controls, allocation schemes and the like are crude and clumsy instruments, which it is absurd to idealise. My own experience confirms the lively account which Professor Jewkes gives of the lengthy administrative process of quite unscientific haggling by which allocation schemes are apt to be constructed. But it must not be supposed that there are no defects in the so-called financial controls which some prefer. When, for example, it is suggested that the need to ration scarce essential commodities might be averted by re-distributing purchasing-power by really drastic fiscal measures, it is well to remember that taxes have their disadvantages and sometimes arouse criticism, that their incidence is not always just or scientific, and that officials have to be employed to assess and to collect them.

The same scheme of analysis which I have applied to foreign exchange rates and the balance of payments can be applied with appropriate modifications to the rate of interest and the balance between savings and investment. During the war, the production of capital goods for peace-time purposes was virtually suspended ; consequently, the current demand for such goods is abnormally high. On the other hand, for various reasons the current rate of private saving is abnormally low. In these circumstances, an tremely high rate of interest might be needed to equate the rate of real investment to the rate of saving, if the demand for capital goods were uncontrolled. There is, therefore, a strong case for regulating this demand. The inter-relations of the capital market and the monetary system introduce many complications ; and I cannot pursue this subject further in this address. It is worth noting, however, that modern economic thought, over-impressed as I think by these complications, is inclined on this matter to abandon the notion of an equilibrium price altogether. It has been suggested that there are no limits,

set by underlying economic forces, to the power of governments and monetary authorities to manipulate interest rates. This palpable exaggeration, as I have always thought it, served to encourage Mr. Dalton in the mistake which he undoubtedly made in carrying the cheap money policy to excessive lengths. The mistake lay in trying to force interest rates down below the long-term norm.

I have concentrated in this address on what I may call the mechanics of the economic problem. My main theme can be summed up in two short propositions; first that, in conditions of large-scale maladjustment, the optimum price is to be found, as a rule, between the long-term norm and the short-term equilibrium price, but lies much nearer to the former; second, that in such conditions, regulation and deliberate direction may be useful and sometimes indispensable. To anyone concerned in a responsible capacity with the actual problems that arise, the latter proposition at least is obvious commonsense. I deplore the fact that it is necessary to argue it among professional economsits. A century ago economists were laughed at as the practitioners of the dismal science. They scarcely deserve that taunt, or should I say that compliment, to-day. I fear it must be recorded that during a period in which the British people have been faced with most formidable economic difficulties, to surmount which it is important above all else to appreciate the magnitude of the effort required, the most extravagant propagandists of go-easy illusions, the most pushing salesmen of enervating Fools' Paradises, have been found among economists of diverse schools of thought. We have now, I hope, done with the illusion that a much better time could be had quite easily by all if only industry were mobilised for national purposes, as it was to produce Fido, and Pluto and Mulberry. It would be no improvement to replace this by the illusion that our present austerities are unnecessary, and would vanish like the snow if the sun of the price system were allowed to shine.

SECTION G.—ENGINEERING

THE YOUNG ENGINEER

ADDRESS BY

WING COMMANDER T. R. CAVE-BROWNE-CAVE, C.B.E.

PRESIDENT OF THE SECTION

THE President of the Section usually bases his address upon some aspect of his engineering work. This has been easily done by most of our Presidents, as they have been outstanding in the profession and leaders in some branch of engineering knowledge. But what am I to do? I entered H.M. Navy as an Engineer Cadet in 1901 and worked through to the long Specialist Design Course at the Royal Naval College, Greenwich. After some years at sea and at the Admiralty, I transferred to flying in 1913. Most of my experience was then in the development and the use of small non-rigid airships, followed by experimental work with the larger rigid airships. When that work was stopped in 1921, I was posted to command the Marine and Armament Experimental Establishment, whose main work was the testing of new types of flying-boats and the development of armament for the R.A.F. This was followed by a year at the R.N. Staff College. I then returned to airship work to take charge of the development of the first heavy oil aircraft engines and the machinery of H.M. Airship R.101. When that ship was lost and the development was finally closed down, I retired from the R.A.F. and was appointed to the Chair of Engineering at University College, Southampton. I returned to the R.A.F. in 1939 for the first part of the war and was employed mainly on aircraft and engine maintenance problems. I was then made Director of Camouflage under the Ministry of Home Security until 1945 when I returned to Southampton.

You will realise from this summary that any detailed description of my practical engineering work would now be out of date and of no interest at this present meeting. I have mentioned my experience so that you may know that although trained in Marine Engineering, my practical engineering experience for the last thirty-six years has been quite different and very varied. It has involved problems so novel that there has been very little practical experience available as a guide. Consequently, I have had to rely upon my knowledge of general engineering principles, supported by reference to the best available books. In this process I was greatly helped by serving on committees and by the advice and assistance of young engineers who had come more recently from universities. I was remarkably fortunate in these colleagues, some of whom have passed to the very highest positions in the academic and the engineering worlds. I derived equal assistance, though of a rather different kind, from men who had long practical experience and a remarkable gift of that engineering judgment which is so difficult to define and harder still to develop by any means other than practical experience.

On going to Southampton in 1931, it was natural that I should approach engineering education with the point of view of the user rather than that of the more conventional academic engineer. Southampton is remarkable in that besides its regular university work it has some 500 engineering apprentices working part-time for the National Certificate and the Associate Membership Examinations of the Engineering Institutions. There are also some 500 evening engineering students working for more elementary technical qualifications.

I have taken many opportunities of discussing how far the engineer graduate and the engineer apprentice of corresponding age have developed the knowledge and characteristics which give them the most satisfactory start in industry or in the practical engineering work to which they go.

I propose now to use this varied experience to review the characteristics and qualities which seem to me to be important for the young engineer, and then to examine the processes by which they are best developed.

This subject is so important that it has been agreed to devote the whole morning session to its discussion. I hope, therefore, that my views may act as a stimulant to bring out your wisdom and the fruits of your experience.

The first step towards deciding the characteristics and qualities which are important to the young engineer is to form a general picture of the kinds of work he may be required to do.

Many years ago Thomas Treadgold defined 'engineering' as 'The art of directing the great sources of power in nature to the use and convenience of man.' In this context the word 'power' must have an extremely wide meaning if the definition is to be at all adequate.

I prefer the longer description of 'engineering' given by Lord Dudley Gordon in his Presidential Address to the Institution of Mechanical Engineers in 1947—their Centenary year.

'Engineering is the great constructive profession, which benefits the world by things made and done, and not merely talked about. The great steps in its progress have been taken by exceptional men who, by "drawing correct conclusions from insufficient premises"—in other words by guessing wisely—and then daring to risk their reputations and their fortunes in putting their ideas to the test, have achieved results afterwards to be explained in detail by the theorists. They used, of course, all the scientific knowledge they possessed, much or little, but their unformulated wisdom known as intuition, and above all their enterprise in using it, was most frequently the cause of their success. Deplorable as it may seem to the academic mind, it has to be admitted that industrial practice has often run well ahead of theory. Water-wheels, for example, were in use centuries before there was any formal theory of hydraulics; the steam engine was brought to a very high degree of perfection more than a generation before there was any science of thermodynamics; steel was hardened for ages before metallurgists could give a proper explanation of it, and we should, indeed, never have had any science of metallurgy at all if steel and iron had not previously been made.

If Marconi had allowed himself to be bound by the theories of the day, he would never have attempted to send wireless signals across the Atlantic before the Heaviside layer was discovered to enable them to arrive at their destination. One of the lessons of engineering history is that great advances have come about by the enterprise of individuals in attempting desirable objects without waiting for others to agree that they were practicable.'

That is an admirable outline. It is longer than Treadgold's classic and will, therefore, not be so easily quoted, but it means much more and will be invaluable to the young engineer when he has finished his formal training in engineering science and is beginning to practice the art of engineering.

Some important developments have resulted from a clear and accurate appreciation of the problem, followed by a reasoned guess at the solution which is best worth trying. The engineer must then be able to devise realistic and intensified methods of test which will give conclusive information about the value of the solution without undue danger, cost or delay. The more realistic and certain these tests, the more daring the developments which can be tried and the better the progress made; but much depends upon the technique of testing.

Other important developments have resulted from accidents which at first appeared mysterious. The engineer must realise the need for systematic collection and investigation of observed facts. He must be able and anxious to build up a complete sequence of explained steps, and from these to diagnose the cause.

An engineer must have a good appreciation of the degree of accuracy which is necessary in his work. Insufficient accuracy may lead to wrong and dangerous conclusions, excessive accuracy causes waste and delay.

In so far as it is possible to give a general description of an engineering task which involves novelty and development, it may be said to include:

1. An accurate appreciation of the requirement.
2. The preparation of a plan and design to meet the requirement.
3. Experiments and development work to extend existing knowledge to cover any special features.
4. The provision of the necessary material, equipment and personnel.
5. The process of construction or execution.
6. The examination and test of the finished work, under extreme but realistic conditions, to ensure safety and fitness for the purpose and conditions specified.

Running through the whole process there are the cogent considerations of cost and efficiency. In a radically new development these considerations may be temporarily put aside, but before the new development approaches the stage of useful application, the factors of cost and efficiency come in again with all their dominant insistence.

The engineer's idea of efficiency considered as a ratio of the result achieved to the expenditure necessary to achieve it is one of the most useful general conceptions. It is a steadying influence which every engineer must regard. It could be applied, to great

advantage, in many other forms of human activity.

What are the knowledge, experience and qualities which the engineer must have in order to control or perform work of this nature?

He must know and thoroughly understand the essential principles of engineering science. He must remember them so well that he applies them instinctively. Much of the detail of their application which has been taught during his formal training will fall into the background and will not be remembered with sufficient completeness to be used without some reference to books or other published work. His knowledge must, however, be such that he can recapture and possibly extend this detail, so that he can apply the methods of engineering science with confidence and safety.

He must have engineering knowledge and judgment based on practical experience, and a creative inventiveness which enables him to devise new methods of overcoming difficulties as they arise. He should have a considerable amount of actual manual skill, particularly in operations which involve a good deal of difficulty. Although it will usually be impossible for him to achieve the great skill of the craftsman in the many processes he will use, he must go far enough to experience the difficulties which are likely to produce defects. By no other means can he gain the instinctive appreciation of the sources of defect and difficulty which he must avoid in the designs he prepares and in the instructions he gives.

He must develop skill in human relationships in order to achieve an effective understanding and co-operation with his seniors, his equals and his subordinates. He must aim at being able to settle down quickly and become a really effective and useful member of a team. Later he will develop the characteristics which will make him a good leader; but most of his early experience will be as a responsible member of a team, and it is in that capacity that he will initially be judged.

He must develop an accurate imagination, which will enable him to predict in logical sequence the way in which each step of a proposed undertaking is likely to work out. This is necessary to enable him to anticipate difficulties which may arise and to devise and provide means for their avoidance or remedy.

Having drawn our general specification in outline, let us now examine its sections in greater detail and study the processes by which the essential qualities may be developed.

Engineering Science.

The engineering science which is used after the conclusion of an engineer's formal training varies greatly according to the type of work he is doing. For certain tasks of research, design or development, he will require to use some engineering science much in advance of what he was taught for his first degree.

Some other engineering work is less scientific. It is based upon established practice but passed on in the form of rules and formulae which can be used by those who have forgotten most of their engineering science. A great deal of practical engineering uses still less science and is carried out under conditions in which difficulties of administration, the climate and the human factor may be so great as to outweigh the more purely technical aspects.

There is a general and natural tendency for engineers to use less engineering science as they advance to positions of more general responsibility. The work of most older men tends to become largely administrative, but it must have a backing of engineering judgment, based upon previous experience, and an understanding of the way in which problems can be solved by engineering science if applied by younger engineers, who are still familiar with its comparatively intricate detail. The engineering wisdom and mature judgment of older men are frequently vital factors because in many engineering jobs the available evidence is by no means conclusive, but a decision has to be reached. This is done by the 'Chief,' who, 'guessing wisely,' makes the vital decision upon which the whole enterprise may hang. For younger engineers and those who are doing design and development, the principles of engineering science are essential and the technique of applying them must be available in reliable form. Much of the knowledge which the young engineer at the age of 30 has to use for really important applications was not included in his formal training. Even if it was in the syllabus of his first degree examination and he was at that time able to answer the rather artificial type of examination question with the speed and completeness necessary to achieve the standard of a good honours degree, he will have lost that ability in a very few years. If he then requires knowledge of a subject to apply to a specific problem where safety of life and much wealth may be involved, he will have to recapture his knowledge in a more thorough and reliable form. He must derive the assistance which he requires from books and various technical publications. The art of using these sources of information for the solution of important problems is one which ought to form a very definite part of his engineering training.

In my own particular case, I had the good

fortune to take part in a series of technical developments of quite unusual novelty and variety which depended upon engineering science far more than does the work of many engineers. What proportion of the engineering science which was needed for this diversity of problems—airship design, the development of high-speed oil engines, exhaust water recovery, evaporative cooling, noise problems and even camouflage—was included in my original formal training in marine engineering ? It must have been far less than 50 per cent.

Basic Principles and Current Practice.

Engineering science includes certain basic principles which are the really important features of each subject. There is a tendency to swamp the basic principles with a quantity of current (or sometimes ancient) practice in their application. Current practice changes fairly rapidly and most colleges cannot keep pace with it sufficiently closely to teach it in really up-to-date form. It may, therefore, be misleading to the student who is faced with a problem shortly after leaving college and loses confidence in what he has been taught because he finds that some of it is not up to date. Current practice should, therefore, in college, be taught only so far as it provides the best examples to illustrate the application of basic principles. The selected examples should be as modern, realistic and interesting as possible. All ancient dead wood should be cut out of the syllabus and burnt.

The magnitude of a syllabus requires very careful consideration. Many syllabuses have become much too long for all except the quickest students. This distension is due to the addition of new material without the removal of an equivalent amount of obsolete material. The syllabus should not be so long that the average student can find no time for thinking and discussing it thoroughly.

We are inclined to drive a new detail into the syllabus because the student might want to use it later in his work. There is no objection provided an equivalent amount is cut out. But it must be realised that an engineer will require a great deal of engineering science which was not in his degree course. He will have to learn it later. We must, therefore, teach him the art of learning for himself from the sources which are available. If he can do that, there can be little objection to omitting an item from the syllabus taught and leaving it to be learned later by those who require it. That is the way to shorten the syllabus.

It is, I suggest, better to carry each of the main subjects of engineering science to a stage at which the engineer has a general understanding of the fundamentals. From this foundation he can advance when occasion requires. It is better to establish this foundation in each of the main subjects than to carry to a rather higher stage, those subjects which the student thinks he is most likely to want, leaving the remainder as totally strange and almost impenetrable country. It is very difficult to decide at the age of 20 which subjects are likely to be most used in a student's future engineering career.

Many of us decry specialisation and a close concentration upon technical subjects to the exclusion of matters of more general interest, which give a wider understanding and a better background. This very sound principle ought to be applied also within the subject of engineering itself. Narrow specialisation in engineering is worse than narrow specialisation on engineering.

An engineer's effective knowledge of a subject must be judged not by his final examination, but by the knowledge which he can retain or recapture some three or four years later, when he wants to use it either for a definite problem or as a general guide. Very few men can remember a subject for a year or two with such completeness and accuracy that they could apply it with safety and confidence to problems of greater complexity and importance than those of the rather artificial type which are set in an examination where six questions have to be dealt with in three hours. In the real problems the solution must be practicable and the calculations must be correct within the limits of safety.

Text-books.

This leads me to the conclusion that courses of instruction should be based upon text-books which must be chosen with a view to future use. The text-book should go rather further than the lecturer can go in the limited time with a class in which the rate of useful absorption may vary greatly. The lecturer will supplement the text with notes to explain, or extend, or correct it where he thinks desirable. The book with these added notes will for many years give the student a command over his subject which will allow him to use it far more safely than if he relied upon memory and lecture notes which may be incomplete or wrong in vital detail. His books may carry him on until he has reached the stage at which his own use of engineering science has become small and he can rely for it upon younger men ' more recently from school.'

If authors and publishers would aim definitely at this continued usefulness and would publish periodical addenda to their

standard text-books, (as is done very well and simply in service manuals), to bring them up to date with current developments, the value from the engineer's point of view would be greatly increased. The true measure of the long range value of a book is judged by the way it can be used by engineers under these conditions. Many engineering text-books are unsatisfactory for future use because they are aimed too directly at the type of question which can be set in an examination. Their examples are taken from examination papers and the whole emphasis of the treatment is directed to passing the examination. It is perhaps natural, though certainly unfortunate, that books of this type should be the best-sellers. It must, however, be realised that they do not make the greatest contribution to the effective application of the engineering science with which they deal.

Technical Publications.

Engineering science and technology are advancing rapidly and a great deal of new work is published long before it can be included in text-books. It is published in the form of lectures and discussions and in special articles in the technical press. The young engineer may be able to keep reasonably well in touch with the new work published in the technical press upon the subject in which he is specially interested, but he is greatly dependent upon being able to find up-to-date information on any subject which he unexpectedly requires. He must make himself familiar with Technical Libraries and other sources of information. Short courses of special lectures are given at various universities and technical colleges. They form an admirable source of information for those who are able to take advantage of them. It is desirable that these facilities should be greatly extended.

The Institutions.

The Engineering Institutions and their local branches are the most important channels through which new technical information is published. The value of their lectures is greatly increased by the discussions which follow. The opportunity of meeting men interested in a particular subject from widely differing points of view is very valuable. The whole occasion of a lecture, and its discussion, constitutes an item of great importance in the propagation of new knowledge and its sober appreciation at its true value.

These various sources are of great importance in helping an engineer to acquire and keep available the expert knowledge on which depend the efficiency and perhaps the safety with which he can do the type of engineering work for which he has been trained.

Investigations.

Technical investigation is an essential process of engineering. Every form of progress or development involves some degree of experiment which must be based upon systematic lines. The technique of investigation depends upon a combination of systematic analysis of the requirement with the more artistic inspiration which shows a promising method of meeting the requirement. A great deal might be learned from a critical study of the methods by which valuable investigations have been carried out. Sometimes they result from sheer weight of experimental data and statistical analysis; sometimes from a stroke of genius which appreciates the vital issue and clears it by a single well-aimed experiment of admirable simplicity. The art of devising experiments and tests which will reach conclusive results quickly, is of immense value. Great skill in the art is unfortunately rather rare. In some men it really constitutes brilliant genius. The art is usually learned by practical experience; I see no reason why it should not, to some extent, be taught by a critical study of past cases.

Personal qualities.

In addition to scientific and technical qualities the engineer must develop skill in human relationships. An engineer seldom works as a single unit. He usually is one of a team. His effectiveness, therefore, depends upon co-operation with his superiors, his colleagues and men who are working more or less definitely under his direction. The qualities which he should develop are closely similar to those which Sir Percival Waterfield recently described as being desirable for the Administrative Branch of the Civil Service: ' brains, personality, effectiveness, judgment and integrity.' This seems an admirable definition of the Civil Service requirement. For an engineer, energy, enterprise and determination are also important qualities in the personal group.

The Civil Service Commission have developed a test to determine the personality, effectiveness and judgment of their candidates. This test has been criticised; but as the Commission is able to follow the history of the men they select it seems certain that they will have adjusted their test so that it does find the men who subsequently do well. The Commision do, however, test only those who have at least second-class honours. I do not know whether such an academic standard is really necessary, but my own experience indicates that a large number of

men who do not achieve it have the personal qualities for which the Commission is looking very well developed.

When we include the qualities of energy, enterprise and determination which are important in an engineer, it is not surprising to find how valuable many engineers who have not attained a second-class honours degree have in fact proved to be.

The attainment of second-class honours in a degree examination is a convenient but not wholly satisfactory test of the candidate's knowledge of engineering science. It is not a good test of the other qualities which are at least as important in a great deal of engineering work.

An honours degree has long been regarded as an essential qualification for many appointments. It is a simple and easy filter to apply in making a ' short list.' It may not have done much harm when there were 'plenty of good men available.' Now that we recognise the importance of qualities that cannot be tested by a degree examination, the insistence upon a good honours degree should be limited to those appointments in which this standard of engineering science is really necessary. Even then we have the difficulty that the degree examination is not a really good test of effective knowledge and understanding of engineering science.

This question leads to a very real difficulty which confronts a university tutor. A student of average ability (and they are the most numerous and the most important problems) asks advice upon this fundamental question. If he works hard and concentrates closely upon his degree work, he is probably 'safe for a second ' but will have little time for those university activities which are said to develop personal qualities. If, on the other hand, he takes full advantage of all the wider opportunities for development which the university offers, he will very probably understand the general principles of his engineering science passably well, but will not have worked up to that speed and standard of examination technique which will gain him second-class honours : without which the Civil Service Commission will not even look at him for the administrative or the scientific officer branches. What answer should the tutor give ?

Most people say that the art of establishing good human relations cannot be taught by lectures. Is that defeatist conclusion justified ? The first thing is to point out to the student that human relations are very important in engineering and that he will learn about them by observation of good and bad examples. Examples of bad technique are specially important as showing what to avoid. Once the student realises how important human relations are, his own critical observation will teach him a great deal and will go on doing so for many years. Is it not possible to give, in a very few lectures, descriptions of good and bad technique and perhaps to lay down some general principles. I have tried it tentatively and it is difficult to judge the result. The lectures are so different from most of those in the conventional engineering course that it may be a relief rather than an aggravation of the academic load of the student. But those students and lecturers who wish to concentrate their *whole* energy on the degree feel that this may be a distraction which should be postponed.

In some men skill in human relationships seems to be innate. In others it was undoubtedly developed at school, perhaps as a prefect or in some position of responsibility, where he had a friendly critic who took the trouble to study his methods and suggest improvements.

I suggest that the same method is the most effective in later experience. He must have responsibility and work out his own method, making his own mistakes, but it is very important to have the friendly critic watching from above and ready to make suggestions.

Communications.

It is only on comparatively rare occasions that a young engineer is able to do what he knows to be technically sound without having to explain it to his subordinates, his colleagues or his seniors. His knowledge of engineering science, his practical experience and his inventive genius may be used to bring him to a certain conclusion which may be much better than that which others would have reached and acted upon in his absence. His valuable conclusion, will be quite useless if he cannot explain it to the others concerned and convince them that his is the right course of action. Without convincing communication to others, his work is sterile. The more important and novel his proposal or his warning of potential danger, the more will it depend upon convincing explanation and the more difficult is that explanation likely to be.

The explanation may be done verbally, perhaps with sketches, or by a report with more definite drawings. It may be at a personal interview or in a committee or in the discussion upon a lecture. It may take the form of a lecture or a report which he himself delivers. Even assuming that he is entirely right, the extent of his achievement may vary from complete and rapid success, to failure with the awakening of some uneasiness or even animosity and annoyance in those he has failed adequately to convince. Skill in these communications contains many factors. Clarity of explanation, illustration

and general arrangement are important. The way the explanation is written or spoken, his personal manner and perhaps also the occasion and circumstances he chooses, may have a great influence upon the result achieved.

Like many other skills, this one may be partly inherent. It is certainly capable of great improvement by careful practice. It is one of those things in which it is wise to review each event in retrospect to assess the effect produced and to determine in what way the explanation could have been better done. Critical advice from a friend greatly helps the review.

Clarity and effectiveness of expression vary enormously between individuals. They control a coefficient by which every technical plan must be multiplied before its effective value can be determined. They are powerful but dangerous weapons. How many valuable suggestions or important warnings have failed and proved sterile because they were not communicated sufficiently well to carry conviction quickly. And, *per contra*, how many unsound schemes have been ' sold ' by sheer skill of exposition which masked an absence of real technical merit ?

The process of clear explanation followed by pertinent, active and perhaps competitive discussion produce a frame of mind so stimulating that useful developments or potential difficulties may appear much more certainly than could be expected under less stimulating conditions. An unskilful discussion may lead to failure or perhaps definite error and personal animosity. A good discussion provides a competitive stimulus to both parties which, if well used, may bring out valuable results.

Practical Experience and National Service.

Although engineering science and technology may indicate the normal method of solving an engineering problem, a great deal depends upon knowledge of what is practically possible and reasonable, under the conditions which exist. These practical limitations are in many cases the determining factor.

Practical knowledge and judgment have to act instinctively in the engineer's mind. They must, therefore, be acquired by the intimate process of practical experience.

It is not necessary for the engineer to develop the dexterity and skill of the craftsman in each of the many trades he will subsequently have to direct. He ought to make a point of doing with his own hands all the more difficult processes he is likely to use. In no other way can he acquire, in really satisfactory form, that instinctive appreciation of practical difficulties and practical possibilities which will make his designs reasonably easy to carry out and to maintain in serviceable condition. The difficulties of tightening, securing and testing the ' inaccessible ' nut are best appreciated by practical experience under adverse conditions.

A great advantage of practical experience and some craftsman's skill, is that they tend to give that confidence and assurance which is well recognised by subordinates, who appreciate these practical qualities more highly than they appreciate the scientific qualities which they understand less.

When the engineer has acquired a good body of practical experience, he will have the knowledge and the outlook which will enable him to learn a great deal more, by critical observation as distinct from personal operation.

Practical experience should be acquired while the student is young and able to get into the position in which he is accepted as a keen apprentice by the experienced craftsman, whose skill and instinct he is trying to understand.

It is, in my opinion, desirable that a good deal of practical experience should be acquired by the student, before he embarks upon the applied engineering science of a degree course. Let him learn his basic science at school, or in a preliminary course, which brings him to intermediate standard. Before he proceeds to the applied science of Part I, he ought to know a good deal of practical engineering, in order that he can understand the significance of the principles he is learning.

This may also be the right stage at which to introduce the year of national service. That year must not be a kind of tax paid by every fit man. It might be a year of very active training, carefully designed to develop the fitness, the mental and physical agility and the courage which are as important in engineering as in the fighting services. For those who are destined for an engineering degree, the first year of apprentice training at Halton would be excellent.

From the engineering point of view, the arrangement seems good. It gives some practical engineering experience at the stage when it is most necessary. It also gives a mental relaxation in what is a very long course of mathematical and scientific training, extending over five or six years from the end of a boy's general education. Many people fear this break in the academic work. If the gap of a year is going to wreck the student's knowledge of mathematics and science before he proceeds to apply it to the engineering of Part I, his knowledge must be in such a volatile form that it is of little real value.

From the military point of view, the period of training at the age of about 18 seems most likely to find the enthusiastic technical officer for a future emergency. At the end of the university course the ablest men are likely to go to industry, or, if a period of service is then demanded, it will be done as a kind of penance before returning to the chosen career.

Many of us now have an opportunity of comparing the undergraduate who has come direct from school with the ex-service man who is taking the same course. The period of service has, in most cases, been much longer and much more distracting than the period of national service is likely to be in future. The ex-service man has forgotten a great deal but he soon recaptures what is necessary. His greater experience and maturity make him an excellent student.

An engineer's practical experience forms such an essential part of his engineering education that it really ought to be planned and supervised as carefully as his course in engineering science. It would be absurd to suggest that one year of national service would supply all the practical experience required. It might be a useful preliminary dose, given at the right time, to allow the coming feast of engineering science to be appreciated and digested in comfort and to good advantage.

When the engineer has finished his meal of engineering science and—we hope—taken his degree, his cogent consideration must be to arrange such practical experience as will enable him to understand the useful application of his engineering science and to choose the particular line of work for which he is best suited.

The period immediately after a degree course should be devoted not to the most highly paid job available, nor to that which will give the most direct application of the engineering science recently learnt, but rather to the work which will best make good the deficiency of practical experience.

Perhaps the most critical step in an engineer's career is the appointment which he gets at the age of 28 or 30. Up to that stage he should always choose that experience and learning which will give him the best qualifications for that pivotal appointment. After that stage he will seek means of applying his qualifications rather than extending them still further. Many of the larger firms have admirable schemes of post-graduate practical training designed to give the student some insight into the real problems and to try his suitability for various kinds of work.

The apprentice who takes his practical experience and his engineering science in thinner layers during a 5-year apprenticeship with part-time work in college, has a better balanced engineering education throughout. He is not able to achieve quite the same standard or thoroughness in engineering science because the time he devotes to it is less and he cannot get the long periods of concentration under academic conditions, which are conducive to this type of work. At the end of his formal training he will probably wish to extend his knowledge of technology in the subject upon which he decides to concentrate. For this purpose special courses at Technical Colleges and also the lectures of the Engineering Institutions are very valuable.

Engineering Courses and the qualifications for entry.

This review of some of the qualities which are important to an engineer : his knowledge of engineering science, his experience, judgment and inventiveness, his powers of clear and convincing communication and the effectiveness of his relations with other men, his seniors, his colleagues and his subordinates, may be interesting. If by discussion we can reach reasonable agreement, we shall have a background against which to examine the education and training which we are providing for young engineers. We must see whether the important qualities are likely to be developed in the right proportion. Are we trying to cram in too much engineering science, which it has been customary to teach in ever increasing volume and, therefore, neglecting the other qualities which are more difficult to teach and to test ?

Engineering education should give the desire and the ability to go on learning. The amount of knowledge taught in the process is only part of the benefit.

If a course forms part of the student's general engineering education, it must not be crammed so full that there is no time for thinking and discussion. The student must not be turned out gorged and sick with a lasting aversion from all the material he has taken in. He should go out well fed and fit. Though temporarily tired, he should be anxious to get more knowledge by his own efforts ; he must know where to find it and how to digest it. We shall not improve quality merely by increasing the academic load.

The catalogue of desirable qualities is long, and we cannot expect any individual to have all of them strongly developed. Their relative importance varies greatly according to the type of engineering work which is to be done.

For research, a knowledge of the principles of engineering science and an ability to find and digest the appropriate published knowledge are perhaps the chief requirements. The definition of the object and an understanding

of the practical limitations are also important, but these factors are in many cases specified by one considerably senior to the man who carries out the investigation.

Technical development requires a great deal in addition to engineering science. A clear understanding of practical limitations and an instinctive conception of possible difficulties are constantly required. The whole process may depend upon the technique of devising and conducting realistic intensified tests which will give conclusive results quickly.

Design may depend upon conventional practice or, if the problem or its treatment involve considerable novelty, upon inventiveness supported by engineering science. It must be linked with good practical experience of production and of practical use.

Production depends upon technical knowledge of the processes and materials, upon administrative skill and the handling of men.

A great deal of engineering work in the field or under adverse conditions of climate and country may be such that the human factor and administrative problems outweigh in importance, the technical and scientific difficulties.

Each of these general types of work demands the engineering qualities in widely varying proportion. It is in many cases difficult to tell which qualities a student will develop most strongly and therefore which type of work he should take as his objective.

Individual initial tastes vary. Some students long vaguely for ' research ' : chiefly, perhaps, because so much has been said about research in general. Others prefer a ' clean ' job even if it is like that of a clerk or a calculator. The man who really wants to be an engineer has an instinctive leaning towards the applied and practical side. He is inclined to shirk the engineering science and particularly the mathematics, partly because they involve hard thinking and partly because they may not be much like the engineering he longs for. He must, however, realise that a great deal of the most interesting developments depend upon science and mathematics and that if he does not follow them to the limit of his ability, he may be giving up the knowledge most essential for the work he will eventually want. He may be surrendering the chief potential advantage he has over many other men.

The education of an engineer during his formal training naturally goes forward from the mathematics and science he has learnt at school. He goes on with these subjects as far as his ability will take him. His science becomes more definitely applied and his mathematics is, or should be, concentrated upon the processes he is likely to require and upon problems of the type he is likely to meet. It is his power to understand science and even more his power to do mathematics with confidence, which set the limit of his progress along this main road.

It is important that the mathematics and the science should not be made harder than is really necessary or of an inappropriate type.

At many points along the main road of engineering science there should be forks by which those who are slowing down may divert into more applied and practical work. These diversions are most important, and they should be arranged so that change into a more practical course does not constitute failure or a degradation to a lower classification.

How many of the engineers who have proved most genuinely valuable (or happy) either as ' leaders ' or as ' followers ' have come out of the very top mathematical bin? I do not think that those who ' peel off ' into the more practical side-roads need be unduly disconsolate ; but at the parting of the ways they should remember the caveat mentioned above.

Some boys leave school to begin apprenticeship at 16 and study by part-time work for Higher National Certificate. Others remain at school longer and obtain Matriculation exemption and perhaps exemption from Intermediate also. Many universities will in future only accept candidates who have cleared Intermediate. They then require three years' work before granting a degree. The degree course, therefore, becomes so exacting that there are likely to be many candidates who stay at school until they are too old for apprenticeship but prove to be incapable of taking the degree course. They will probably wish to prepare for the Associate Membership examination of one of the Engineering Institutions. A part-time course will be difficult to arrange because engineering firms may be unwilling to release, for part-time work in College, men who are not apprentices. There is already a considerable demand by ex-service men for such a course, especially in Civil Engineering. It seems likely that the demand will increase as the course for a degree becomes longer and more difficult. Into such a course those who fail at any stage in the degree course might very well transfer. Those who have passed this examination and have the practical experience necessary for associate membership are likely to be in great demand although they have not quite the same standard of mathematics and engineering science as the engineer graduate.

There will always be a great demand for short courses given by specialists describing recent technical developments. They can be rather more thorough than a single lecture

to an Engineering Institution. They should presumably be given in the evening in a Technical College.

The engineering degrees; the Associate Memberships with their essential requirement of practical experience; the Higher and the Ordinary National Certificates taken by part-time work simultaneously with practical experience—are all too well-known to need description.

The National Certificate courses prove to be too exacting for a large proportion of those who enter the first stage. Of 100 who enter Stage 1 only about 26 get the Ordinary, but of these 20 will get the Higher National Certificate. The remainder mostly lose interest and drop out completely. There must be more practical courses into which they can go at the beginning or at any later stage. The City Guilds of London Institute and similar authorities arrange examinations which call for a good standard of practical skill and knowledge of the principles upon which the practical processes depend. They do, however, require a higher standard of mathematics and, for examination purposes, a readiness and speed of verbal description which is greater than comes at all easy to some men whose skill is in their hands and judgment.

The Craftsman's Certificate.

There appears to be an additional requirement for a Craftsman's Certificate to cover, primarily, practical manual skill and judgment. It should include an understanding of the technical principles, although it may not be essential to pass a written examination in these principles. A certain amount of sketching, the reading of drawings and the making of calculations are desirable but they must be of a type and of a standard no higher than a craftsman will really be called upon to use in his work. The craftsman's practical skill and judgment are the main things and by them he should be judged. Other subjects, though necessary in limited measure, are subsidiary.

Men who could take such a course with advantage are numerous but the demand will always be great. They are craftsmen much more valuable than the machine-minder-operative of very limited skill. The courses should have a definite standard of qualification which must not be regarded as technically or socially inferior to those present courses which involve a little more mathematics but not equal practical skill.

Selection of Candidates.

Fortunately we have not reached the stage when those entering engineering are selected by a national authority and no others can get in. The boy who is determined to be an engineer or to enter a certain branch has, in his determination, such a precious asset that he is a very promising candidate. But the number of real enthusiasts is much smaller than the total demand for engineers.

The selection of candidates suitable for engineering, their sorting into the most appropriate channels and the diversion of those manifestly unsuitable, are steps which are very important for the individual candidates. They are equally important for Engineering, which so greatly depends upon the quality of the men in each stage of each branch.

Are we giving to schools and to those who advise on these difficult choices, a sufficiently clear outline of the nature and requirements of engineering to allow choices to be made on good information?

Mathematics.

Mathematics appears to be the factor which limits the progress of a student along the main engineering science road and ultimately makes it necessary for him to divert into a more applied road.

It is important that mathematics should be taught in a form which does not constitute a road-block prematurely.

Engineers like to see a practical significance in all they do. They must therefore be enabled to see mathematics as a tool, which they can use to solve practical problems. They must have confidence in using it for future work.

The mathematical technique which introduces devices and conceptions which are, no doubt, essential for a mathematician's work and valuable for his mental training, may seem quite artificial to the engineer's mind and is never likely to be used by him with any confidence. It must not be a block which alone stops his progress up the main road.

The mathematical treatment which gives successive approximations, which develops accuracy step by step until the necessary standard is reached but no further, is much more likely to be of continued use to the engineer. It is much more appropriate mental exercise because it develops the idea of successive approximation which is a fundamental part of an engineer's outlook.

A great deal depends upon the technique and the outlook of the lecturer. Many believe that it is good for engineers to be taught by a mathematician because they acquire his outlook. But is this what they want? It may be better that they should learn from an engineer who has experience and confidence in applying mathematics to real engineering problems. That is the art

they want to learn and he is likely to be the source they will best understand.

The problem of teaching mathematics to engineers is necessarily bound up with the forms of mathematics which engineers can use to greatest advantage. These are matters of such importance that we have arranged an inter-section discussion with Section A under the title of ' Applicable Mathematics.'

Instructors.

In the education of an engineer a great deal depends upon the engineering wisdom acquired from the instructors, as well as the more definite science and technology which they teach.

It is, therefore, desirable that instructors and lecturers should have active experience of applying to real engineering problems the principles and technique which they teach. The skill of engineering teaching and lecturing increases greatly with experience. It would therefore be unwise to depend for lecturers, mainly upon men who come from industry to teach for a short time. Men who come from industry to give a few special lectures are very valuable. It does seem desirable that lecturers should maintain close personal touch with industry and that they should undertake, for industry, investigations similar to those which most of their students are likely to meet. The more abstract type of research is perhaps less appropriate, at any rate as a supplement to teaching.

The lecturers' touch with industry and its problems will help their students—and industry—in many ways.

It is important that the lecturer's outlook and his teaching should be directed to a future application of principles to real practical problems. The final examination is not the correct objective. Students instinctively work for the final examination. The lecturer must keep them on the right target.

The extent to which the instructor can convey engineering wisdom and help the development of personality depends upon how deliberately the course can be taken and how much time and opportunity there is for incidental discussion. If the instructors are really good, these incidentals may be very valuable, but the course must not be filled so full that no opportunities arise.

Examinations and Tests.

Engineering is studied for the purpose of being put to practical use. The teaching throughout the course should undoubtedly be based upon the future use of the knowledge taught, and the establishment of a foundation from which the student can advance to further knowledge by his own study. It should enable the student to step up on to a higher plane of applicable knowledge on which he can work with confidence. Its aim is not the examination or some form of high jump, which the competitor ' clears ' on one supreme occasion with all the artificial technique of a ' roll,' to arrive a moment later at the soft surface of the sand-pit at the same level from which he started.

The test which ought to be applied at the end of the course may have two objects. It must give the student a label which describes the proficiency he has attained in the subject-matter of the course and his probable ability to apply that knowledge to useful purpose. It may also have to determine whether the student is capable of proceeding to a more advanced course. The first is, in most cases, the primary consideration. Selection for a more advanced course may depend partly upon this test but should be based very largely upon the instructor's judgment and possibly upon a special test in the subjects which will be required for the higher course. Admission to the higher course should not be a prize awarded for meritorious work in the last. It should be given to those most likely to benefit by the next.

In all courses where success depends mainly upon a critical examination, provision ought to be made for unsuccessful candidates to retake, on a later occasion, the subjects in which they failed.

The decision whether a student should continue to study a subject in which he has failed should depend upon whether his future progress with it is likely to justify the time and effort expended. This is a matter for judgment and should not be an automatic consequence of the examination. It depends partly upon whether he would be keeping a more promising man out of the course and whether he himself would be better employed on other work.

As men pass up a channel of engineering education and gradually reach the limit of their useful progress along the main stream, there must be side-streams into which they can divert and work for a definite qualification which will use the knowledge they have so far learned and extend it in a more suitable direction. The idea that a product which does not come quite right the first time is useless and must be put aside without improvement and re-test is so unlike good engineering that we should not adopt it with our most precious material.

The examination is a valuable stimulant. It is in most cases the only form of wholly independent test which can be applied. The work which the student does during his course must be given consideration whenever possible because it can be made so much

more representative of future practice than can the necessarily artificial questions of an examination in which six have to be ' done ' in three hours.

If the judgment of the instructor is to be taken into account in assessing either the student's ability to apply what he has learnt or his suitability for a higher course, it is most important that records of past students and their subsequent performance should be kept. Skill in this judgment develops greatly with experience ; provided data are systematically collected.

Industry and the Profession can make a great contribution to the improvement of engineering teaching in the widest sense, if they will critically scrutinise the men who come to them fresh from training and will pass back constructive suggestions and information.

I do not think that these suggestions should carry too much weight in controlling the course of instruction. That is the sole responsibility of the staff in charge of instruction, but the suggestions are valuable evidence on which the staff will act so far as they deem fit. Theirs is the responsibility for giving the best long range educational value and this is not properly measured by suitability for the first job.

The young engineer is greatly dependent for his development upon the more experienced man under whom he works after the end of his formal training. The latter may not wish to be too ready to give blame or criticism. He will realise, however, that if his criticisms are constructive and clearly directed to the improvement of the young engineer's effectiveness and development, their value and encouragement is almost certain to be recognised.

Other Interests.

What ' other interests ' are specially suitable for an engineer ? The ' interest ' should have started in the family or at school because its existence during the arduous period of training may be very valuable. There is much to be said for something which involves manual skill and in which improvement is produced by experiment.

On the other hand, a good manner and easy co-operation with other men are so important that an interest which develops these qualities is certainly appropriate.

What should the engineer read as distinct from his engineering ? There is a great deal to be said for biographies : not necessarily of engineers but preferably of men of action rather than philosophers. Human nature changes much less than does engineering science, its study in biographies is interesting and may be very valuable.

I do not suggest that the young engineer has the personal qualities I have mentioned less well developed than they are in his contemporaries. He shapes very well in such a comparison. I have tried to explain these qualities because their importance is not always fully realised.

There is, perhaps, one improvement which might assist the Students of all Faculties. The later part of their education is taken at a University in order that they may get into touch with other students and other subjects. Their time is however too fully occupied with their own subject. If each Faculty of the University gave one or two general lectures for the benefit of others, it would be much easier for students to begin this extension of their interests. Subsequent extension might follow naturally, but the first step is a difficult one.

May I conclude with a few general points ?

I do not suggest that engineering education is at present ' all wrong.' It produces very good men. But the world is competitive (even if that doctrine is for the moment out of fashion). Our constant aim is to improve.

We are told that the rate of production of engineer graduates must be doubled. The training of more practical engineers must increase at least in proportion. The provision for engineering education must, therefore, be greatly increased and this can only be done wisely and efficiently if we know, as a result of thorough discussion, what we want.

There are some points which seem to me specially important and upon which I am anxious to get the benefit of criticism in the light of your much wider experience. May I, therefore, submit :

1. That an adequate description of engineering and its various branches must be available at schools and to those who have to choose at entry and at subsequent stages. The choice must be made on good information about the nature of the work and the knowledge, skill and personal qualities desirable.
2. That the general structure of engineering education should be reviewed so that it is possible for candidates to enter at any appropriate stage. Changes from one course to a more suitable one should be simpler than at present, and there must be fewer ' casualties ' who fall out and go no further.
3. That courses of instruction should be aimed at the future application of the skill and knowledge taught. They must teach the essential principles and establish a foundation from which the student can extend his knowledge. They must give a fund of knowledge (mainly in

books) to which the student can refer for accurate detail when he requires it for application to real problems.

They must develop the art of learning from these sources by independent study. Syllabuses can then be shortened and there will be more time for discussion and thorough understanding.

4. That it is better to teach the general principles of all the main engineering subjects than to abandon some and carry one or two selected subjects to a rather higher stage.
5. That mathematics must be taught in really appropriate form as a useful tool.
6. That practical experience during the early stages of engineering education is so important that it should be organised as carefully as work in College. A student should have some practical experience before he begins a degree course. The year of National Service could, if suitably adapted, be most valuable for this purpose.
7. That personal qualities, judgment, effectiveness, enterprise and determination are so important that they must be considered in the selection of a candidate and must be developed throughout his training.

Finally.

Engineering is an art and a profession upon which we depend for our prosperity in peace and for our survival in war.

It depends partly upon engineering science but chiefly upon the personal qualities, technical judgment, wisdom and enterprise of the engineers; and upon the practical skill, experience and reliability of the craftsmen.

Steady improvement in engineering education is at least as important as developments in engineering science and practice. It is for that reason that I have attempted this very broad review of 'Young Engineers.' I should not have presumed to do so if I had not been able to rely upon the moderating influence of your discussion to bring the outline into reasonable agreement with the wider experience of more representative engineers. Our review will then have some useful value as a guide to what we hope will be 'done and not merely talked about' in engineering education.

SECTION H—ANTHROPOLOGY AND ARCHAEOLOGY

FOLK-LIFE STUDIES IN BRITAIN AND ABROAD

ADDRESS BY

R. U. SAYCE

PRESIDENT OF THE SECTION

1. *Introduction.*

If the presidents of Section H had been free to follow their natural inclinations, most of them would have devoted their addresses to aspects of research in which they were personally engaged. This morning, I feel it my special duty to try to present to you a very broadly treated sketch of the state of folk-life studies in this country. I should have liked also to describe what our neighbours in Europe are doing, but this is impossible, for it would require at least an hour to tell you about the important work which is going on in Norway, or Sweden, or France, to mention only the three countries on the mainland which I know best. I shall, however, make a few references for the sake of comparison as occasion will permit. It would be much to our advantage if I could say something about Eire, which in this respect at least is different from England, since her practical good sense and power of organisation have enabled her to produce a vast quantity of work that is of the highest value to European scholars, while the unworldly Englishman appears to be lost among his dreams.

The situation, as it appears to me, is a very peculiar one. Up to about thirty years ago Britain stood squarely in the front rank of European research, and her right to do so was widely acknowledged. To-day, in moments of impatience, one is tempted to wonder whether our subject has enough vitality to survive or whether it is not ripe for absorption by some more active branch of study. More careful observation will, however, soon convince us that this is far from being the case, and that the country is producing its customary crop of individuals, each one busily going his own way, often with little interest in and less desire to interfere with the harmless hobbies of his colleagues, and with still less intention of allowing himself to be organised by any one. We are like a pack of beagles that has outrun and lost its ageing master; the pack is splitting up and each hound is hunting his own hare without a single call on the horn to encourage and rally them.

2. *What is Folk-lore?*

Although the term folk-lore was used just over a hundred years ago, there is still lack of agreement about what it means. Some would equate it with the ethnology of modern peoples; others consider it as a collection of survivals from the past. Some restrict their interests to particular aspects of culture, such as stories, material objects, or old ceremonies, while other students think of it as including every side of folk-life, though there are several different opinions about who the folk are.

The whole trend of modern ethnology emphasises the importance of studying a culture as a whole, and of trying to understand how one element is interlocked with and influences other elements. The beliefs, stories, and festivals of a people are intimately related to the nature and times of their seasonal activities, to the variations in the quantity and nature of their food supply, the way in which the population is dispersed over the country, the sentiments and ideals which colour their outlook, inspire their visions, and influence their actions. The change from the compact village surrounded by its open fields to the isolated farm with its enclosures brought fundamental changes in practice, in social relations, and in the mental background. There have been in our own times further striking changes associated with the introduction of modern machinery into farming. Not so many years ago we could see harvest fields full of folk, brown from long days in the sun, socially stimulated by the congregation of unusual members of both sexes, ready for all kinds of jokes and competitions in strength, skill, and endurance, rewarded and exhilarated by the successful fulfilment of a year's work in co-operation with nature, and grateful to the giver of all things for the year's provision, which was about to be safely lodged in the barns. Nowadays the work may be done by a couple of men with a machine. It is easy to

see that the material change from the sickle to the mechanical harvester has brought with it equally important changes in custom and mental outlook.

It would be easy to adduce many instances of the inter-relation of culture elements. The passing of the sailing ship must have caused the loss of many old customs and beliefs, as well as of good songs. The inter-relation of dance, music, and poetry are well known, and many of the old occupations, such as rowing, spinning, and reaping, had their own musical accompaniments fitted to their appropriate rhythm.

These examples might suggest that it is change in material things that leads to change in intellectual things, but the reverse process is probably the more important in the long run. Houses, furniture, pictures, and sculpture undoubtedly reflect the state of mind of their period.

3. *Departmentalism.*

It is, therefore, very important that folk-lorists, while of necessity following their personal interests, should try to avoid an excessive fragmentation of the subject. Twenty-five years ago, Principal John Murray spoke in another connection of the value of studying 'the total life of a society of sufficient volume, duration, and richness' (*Geography*, December, 1922), and it is scarcely necessary to point out the interest of folk-culture with its innumerable regional variations, and the changes that can be seen taking place, now almost imperceptibly, now abruptly, as we trace it through the centuries.

In England the danger of losing sight of the whole culture is increased by the existence of separate societies devoted to dialects and place-names, song and dance, stories and beliefs. I do not for a moment regret the existence of these societies; they are probably necessary to the active pursuit of their special interests, but as far as I know each society acts as though the others did not exist. Yet the work of any one of them ought to be of the greatest value to the others, and it is very desirable that some intercourse and co-operation should be established between them.

At this point, I must draw attention to a peculiar gap in our organisation. There is no society that specialises in the material culture of the folk. Occasionally a paper may appear in an anthropological publication; more often others are found in historical, archaeological, architectural, or agricultural journals. Several good books have appeared in recent years, but little notice is taken of them in any folk-lore periodical, and the authors do not always appear to be aware of work being done in other countries. On the whole the general impression is one of what a recent writer in the *Times Literary Supplement* called luxuriant inaccessibility.

The lack of suitable periodical literature dealing with material culture is all the more remarkable because it seems to be in this branch that work is being the most actively carried on in Britain, apart from that connected with music and dance. Many museums up and down the country are busy collecting. Some of them are financed by municipalities or learned societies, others are due to the energy and devotion of private citizens. We have only to call to mind such examples as Alton, Salisbury, Hereford, Tickenhill, Rufford, Keighley, York, Cambridge, to name only a few. The curators and their colleagues have no suitable journal to supply the knowledge they need, to discuss the wider problems, and describe similar work being done abroad.

The last topic has brought us to the general question of museums in this country, though I cannot, of course, discuss here the services which they will render to folk-culture. We have heard with much pleasure of the large scale plans for an open-air museum at Belfast, of the interesting developments at Blaise Castle, Bristol, and of the establishment of a great national folk museum in Wales. England, as I have mentioned, can show a multiplicity of local efforts, each, according to our ingrained feudal tradition, the result of some energetic group or even individual, and all going their own ways, but where is the organised national effort to compare with those in Stockholm, Oslo, Paris, and Cardiff?

In 1929 the Royal Commission on National Museums and Galleries emphasised in its final report the need for folk museums, and two years later the Government set up a committee 'To consider the recommendations of the Royal Commission . . . that a Folk Museum should be established if possible in London, and to advise as to the practicability of establishing such a museum.' This committee finally recommended that the proposed museum should consist of a composite but typical village, such as would 'demonstrate the main phases in the development of English social life and custom prior to the Industrial Revolution.' Then came the financial troubles. Is it too much to hope that the scheme, limited in scope as it is, and in spite of its long suspended animation, is not quite dead?

It should, of course, be made clear that a British substitute for Skansen would be very incomplete without a national equivalent to the Nordiska Museum, where we could illustrate the enormous variety of British artifacts, and where we should have a centre capable of inspiring research, of carrying out its own investigations on a national scale, and

of publishing those monographs the lack of which, our colleagues abroad tell us, is seriously handicapping European studies.

4. *Space-time studies.*

In what I have already said there is implicit the need for co-operation with other subjects, and it is necessary that I should now say a few words about the relation of folk studies to two sets of disciplines which deal, roughly speaking, with space and time, i.e., to ethnology and history, the latter taken to include prehistory. The first need not detain us long. For a century or so, British folk-lore has been closely in touch with ethnology, and there cannot be the least doubt that it has richly profited by the association. Nor should we now turn our backs on this source of help and guidance. Nevertheless we must remember that there are other subjects from which we can obtain equally valuable benefits, but of which we have of late failed to take all the advantage that we might have had for the asking. Valuable in many respects as have been the studies of native peoples in Australia, Africa, and other parts of the world, we cannot expect them to provide us with full information about the historical development of British agriculture, the evolution of our houses and costumes, the rich variety of our implements, utensils, and furniture, nor about many of those national and individual experiences that have moulded men's minds in these islands. 'Man is explicable by nothing less than all his history' (Emerson).

The neglect of historical studies has seriously retarded our progress during the last thirty years. After referring to one exceptional writer, Lord Raglan said in his Presidential Address to the Folk-Lore Society (*Folk-Lore*, June, 1947), 'It does not seem, however, that . . . anyone else has made a serious attempt to relate folk-culture to the known facts of peasant life in mediaeval England, and it is much to be regretted that the study of folk-lore has failed to attract our leading mediaevalists and social historians.' I do not know how much information about traditions and popular customs still lies in the masses of ancient manuscripts. A recent attempt to obtain from history books some knowledge of the seasonal bonfires of the Middle Ages surprised me by the paucity of the results. There are, of course, abundant references to this and to other popular customs as far back as Tudor times, but Mr. G. C. Homans in his book, *English Villagers of the Thirteenth Century*, says, '. . . just how Mayday was kept in the thirteenth century we do not know,' and on another page, after quoting a reference by a monk of Winchcomb to St. John's Eve bonfires, he adds, 'the fact that in a few instances like this of St. John's Eve the practices of the festivals of the husbandman's year can be proved to have been the same in the thirteenth as they were in the nineteenth century gives us better reason to *assume* (the italics are mine) that there was a similar continuity in the larger mumber of instances in which it cannot be proved.'

Mr. Homans is probably quite right in believing in this continuity of tradition. Nevertheless we should be poor scientists if we were content to build our science on assumptions, without doing all in our power to prove them. The results of recent work in Sweden should put us on our guard. For instance, a very common assumption has been that the custom of lighting bonfires on May Eve and Midsummer Eve has continuously survived in this country from remote antiquity, and I am not prepared to deny its probability. Nevertheless Dr. J. Edjestam (*Årseldarnas samband med Boskapsskötsel och Åkerbruk i Sverige*) has recently stated that the May Eve bonfires, now known from almost all parts of Sweden, had a much more limited distribution as late as the middle of the 19th century, when they were restricted mainly to the central and eastern parts of the country. He believes that they were introduced about the end of the Middle Ages or a little later by people from Lübeck and Holstein who settled in Stockholm, whence the custom spread into the adjacent districts. According to the same writer the practice of lighting bonfires at Easter came to Sweden with the Dutch immigrants who founded Göteborg, and spread into the hinterland of that city.

Over fifty years ago, Sir Laurence Gomme warned the members of the British Association against similar pitfalls. In the *Report* for 1896 (pp. 626–656) he pointed out that 'the comparative method of enquiry has been used to an extreme extent. . . . Even the great work of Grimm is open to the criticism that it does not *prove* the antiquity of popular custom and belief—it merely states the proposition, and then relies for proof upon the accumulation of an enormous number of examples and the almost entire impossibility of suggesting any other origin than that of antiquity for such a mass of non-Christian material.' Some European scholars are to-day actively opposing the belief that many elements of folk-lore date to pre-Christian times, and they are prepared, as we shall see later, to suggest other origins than that of antiquity for much that we have taken to be ancient. There is certainly much of great interest in their arguments, but I think that we can still make a strong case for the high antiquity of many beliefs and customs, as Dr. André Varagnac is doing in France. The new controversy is a welcome stimulant, and it is hoped that

British folklorists will carefully re-examine the foundations of our subject.

It is largely to history, in a wide sense, that we shall have to appeal, and there is undoubtedly a rich harvest to be gathered from the records of the manorial courts and other early manuscripts. Those who are interested in the work and lives of the people can, as is well known, obtain from these sources a vast mass of information, though it may be that they will tell us more about the practical sides of life than about such things as popular customs and beliefs which the old writers probably assumed that everyone knew. It would be of the very greatest interest if we could learn more of what the people thought about nature and about their own customs. To what extent were they animists? What were their ideas about the unseen powers? Was the corn animated by a spirit or by spirits that could take on various visible forms? These questions are being much discussed abroad, and neglected at home.

There is another but closely allied set of problems in connection with which history can be of the greatest help. I have sometimes received the impression that folk-lore has been regarded as something surviving from the very distant past, and that it is comparatively static apart from a gradual fading away. A little thought has, of course, made it clear to me that there have been great, and sometimes drastic, changes during the centuries. Professor van Gennep tells us that many popular ceremonies and fêtes disappeared in France during the Revolution (*Manuel*, vol. III, p. 337). John Aubrey ascribed similar effects to the Cromwellian Revolution in England, and the Reformation swept away not only many festivals and beliefs, but even the names of the Saints with whom many of them were associated. Apparently the functioning of our not inexpensive educational system, combined with the intellectual climate of the times, has had even more fundamental effects on the youths of our secondary and public schools, and has swept out of their minds all knowledge of 'their nature, their purpose, and their destiny' (B. G. Sandhurst, *How Heathen is Britain*, p. 17).

It is a curious thing to note how frequent are the references to the fading away of folk-lore. The Rev. Elias Owen, who collected much valuable tradition in North Wales about the 1880's, said that he could at that time obtain good records only from the old people. Just over a hundred years ago, three appeared a letter from 'Ambrose Merton' (W. G. Thoms) in *The Athenaeum*, August 22, 1846, asking for help 'in garnering the few ears which are remaining, scattered over that field from which our forefathers might have gathered a goodly crop.' We can imagine with what enthusiasm folklorists like Owen and Thoms would have welcomed an opportunity to collect the pure and living lore of the folk in the eighteenth and early nineteenth centuries, especially in those remote mountainous regions untouched by modern industrialism. And yet, General Stuart (*Sketch of the Manners and Character of the Highlands of Scotland*) wrote in 1825, 'superstitious rites and ceremonies . . . were common thirty years ago, but they have now disappeared even among children.' Fifty years before the publication of Stuart's book, Thomas Pennant had felt that an old world of thought was passing away, even in the wild Rannoch country. He recorded that it still retained some of its superstitions, but he goes on to say, '. . . they decline daily, but least their memory should be lost, I shall mention several that are still practised, or but very lately disused in the tract I passed over' (*Tours in Scotland* II, 95 (1775)). He mentions expressly that witchcraft had ceased almost immediately on the repeal of the Witch Act in 1736 (*op. cit.*, I, 97). Even on Islay ancient superstitions lurked 'only among the very meanest of the people' (*op. cit.*, II, 230).

Going back again nearly a century and a half, we find that Bishop Corbet, who died in 1635, had written in his well-known poem, 'Farewell rewards and fairies,' a lament for the disappearance of the fairy belief:

> 'But now, alas! they all are dead,
> Or gone beyond the seas,
> Or further for religion fled,
> Or else they take their ease.'

This reminds us of Chaucer's still older statement about the fairies:

> 'I speke of many hundred yeres ago;
> But now no man can see non elves mo.'

If our traditional beliefs had been continuously fading away for so long, it would have been surprising if any of them had been left in the twentieth century. Either the old observers were mistaken about the amount of superstition that existed in their days, or some other process must be at work. There are periods when superstitious beliefs are not in general favour, but survive among children or 'among the very meanest of the people,' to be followed by other periods, perhaps of unrest and uncertainty, when the old beliefs once more circulate freely in the open. G. W. E. Russell mentions a good example of this. I will quote his words. "A lady who was born in 1801 returned in the eighties to London after a long retirement in the country. I asked what was the change in Society which struck her most forcibly. She instantly replied: 'The growth of superstition. I

hear men and women, apparently sane, gravely discussing such things as second sight, apparitions, and divination. In my youth people who talked such stuff would have been put in Bedlam. Their friends would have wanted no further proof that they were mad'" (*Collections and Recollections*).

These cyclic fluctuations of tradition deserve further study. Can we assume that many of the beliefs, and even customs, that have been well known in recent times were equally widespread in the Middle Ages, or did the Church with its ceremonies and teaching so fill the lives of the people that they had little need for anything else? The importance of Christmas, Easter, Whitsun, etc., may have led to the neglect of some of the pre-Christian festivals and customs, which may have re-emerged when the Church lost its dominant position at the Reformation, just as seeds which have lain long in the soil spring into life and flourish when a wood has been felled.

Mr. W. S. Gwynn Williams thinks that something of this kind has happened with Welsh music (*Welsh National Music and Dance*, p. 64). "The inspiration of nearly all the most characteristic melodies seems something deep down and far back in the life of the Welsh peasant; and, if there is any ground for the suggestion mentioned by H. Idris Bell that a new note in Welsh verse of the nineteenth century 'may be due to the emergence to literary consciousness of a class which found no voice in mediaeval poetry, that Iberian pre-Celtic race which the bouyant joy-loving Celts subdued,' there certainly would seem to be every reason for the suggestion that the present-day popularity of Welsh modal folk-song is due to the emergence to musical consciousness of a class whose distinctive song until recently was entirely ignored by the bardic and professional classes generally."

We are witnessing at the present day what may better be called a re-introduction of an old custom. Cremation, which was first introduced in the Bronze Age, had a long history in this country, and it looks as though it may now re-establish itself as a popular custom. The *Manchester Guardian* (16/9/1947) quotes a statement that 'Britain now leads the world in cremation.' During 1946 there were over fifty thousand cremations in Great Britain, the highest ever recorded. The custom is returning, but not, presumably, the Bronze Age interpretation of it.

Temporal fluctuations in the strength of irrationalism have not been confined to the last few centuries. Professor Martin P. Nilsson states, "The sharpest contrast between the classical period and late antiquity is in the increasing spread of superstition and sorcery during the latter; the mentality of the age had changed fundamentally, an alteration which may be seen also in its predilection for marvellous stories" (*Greek Piety*, 1948, p. 163). On the previous page he also writes very happily on this subject. "At a time when simple, clear lines of thought are in favour, superstition shrinks into its covert; so it was in the last century, and so it was in the classical age of Greece. But superstition does not die; it merely bides its time and spreads abroad again when the mental atmosphere changes and becomes favourable."

The seventeenth and eighteenth centuries folklorists who thought that belief in 'ancient superstitions' was on the point of dying out would have been surprised if they could have known how much the twentieth century was to retain connected with magic and witchcraft, omens and mascots, lucky and unlucky acts, fortune-telling and crystal gazing—and that not only in remote country districts but in the great cities.

A speaker of the B.B.C. (Country Questions, 6/6/48) mentioned cases of telling the bees of a death in the family which occurred in Devonshire in 1947 and in the New Forest in 1948. Another B.B.C. speaker (Country Magazine, 16/5/1948) related how in 1935 a veterinary surgeon visited a farm near Llangollen on which the calves had been dying. He diagnosed the cause of the trouble, only to be told that he knew nothing about it. The owner was not on speaking terms with the young man on the next farm, and, since he had inherited the knowledge and books of his grandfather, a well-known wizard, it was clear that he had cast a spell over the animals.

The *Daily Sketch* (21/1/1946) reported that a number of sailors were charged at Liverpool with refusing to sail with their ship. Their defence was that the ship was haunted by the ghost of one of their shipmates, who had jumped overboard and been drowned. The *Daily Mail* (31/5/1946) described a series of ghostly troubles in a Chatham barracks. A young naval rating on sentry duty heard a ghostly crutch tapping behind him on the ramparts and dashed in panic to the guard-room. Several other men protested against going on sentry alone between midnight and 4 A.M.; one said that he had seen the figure of a man dressed in the naval uniform of Nelson's days hobbling along the ramparts on a crutch.

The *Manchester Guardian* (7/1/1948) reports that a Devonshire church may have to be reconsecrated, because the vicar believes that someone has practised black magic in it.

It is plain that if we are to understand our traditional culture we must approach much of it through history. The content as well as the vitality changes; some elements appear to die out, for the time or for good, and new ones come in 'Doctrines vanish without a

direct assault ; they change in sympathy with a change in apparently remote departments of enquiry ; superstitions, apparently suppressed, break out anew in slightly modified shapes ; and we discover that a phase of thought once, as we fancied, definitely established, is but a superficial modification of an old order of ideas ' (Leslie Stephen : *History of English Thought in the Eighteenth Century*, 1876, vol. I, p. 3).

What I have been saying may imply that I am slipping back into thinking of folk-lore as consisting mainly of superstitions and survivals. The need for a historical approach is, however, equally necessary in the other branches of our studies. Let us give just a moment's consideration to folk dress.

It is noticeable in several parts of Europe that folk costumes are giving place to the standardised clothes of European and American cities, and the same thing is happening to the native clothing of African and American tribes ; but the European folk styles are not all very old. Professor A. Dauzat makes some interesting references to them in his book (*Le Village et le Paysan de France*, 1941). The old country dresses, he says, illustrate fashions which were popular in the cities or among the upper classes a century or perhaps two or three centuries earlier. The peasants in adopting them have changed them to suit their needs, tastes, and resources. Most of the Swiss peasant dresses worn during the second half of the nineteenth century are descended, with some local adaptations, from those worn in the eighteenth century among the higher ranks of society, and those in their turn were copies, more or less out of date, of Parisian styles. The ensemble of the Breton man's dress is clearly derived from the working dress of the seventeenth century

Facts like this might lead us to think of fashions spreading in a series of waves from the cities to the countryside, or from the gentry to the peasantry. The process would go on much more slowly in the past than in our own days, and the new styles might reach some districts much later than others. There might in fact be a time for a certain fashion to adapt itself so well to a particular district that it would become rooted there as a folk dress and that it would resist later fashions. In this way regional styles could arise. Lord Raglan has pointed out how different period costumes have survived in special social and cultural nooks in England, e.g. the uniform of the Yeomen of the Guard, and various university and legal garments. In *Folk-Lore* (June, 1947) he mentions that the steep-crowned hat was introduced from France to the court of Charles I, where ladies adopted it as part of their riding dress. A little later the peasantry began to wear it, but it soon went out of fashion, and by the end of the seventeenth century it was worn in England only by old peasant women. I think it may have survived longer in Wales ; it was worn in Montgomeryshire in the nineteenth century, but its cost made it uncommon among the cottage women.

Even when dresses like those of Brittany have established themselves, they do not necessarily become quite static. ' As long as a costume is alive,' says Professor Dauzat, ' it evolves ' (p. 131). Sébillot saw some of the head-dresses in northern Brittany gradually changing during his lifetime.

Before applying these conclusions to other countries, we should study the local evidence. It may be that other countries were less ready to accept new fashions from cities or anywhere else. I believe that some of the public authorities in the Swedish rural areas had very definite opinions about the propriety of introducing novelty into the local dress. It is possible, too, that the dominance of the towns may not have been everywhere and at all times as great as in France during recent centuries. I have not seen it claimed that the Scottish or Irish kilt was a product of Edinburgh or Limerick.

It is plain that other aspects of folk-life require historical studies to demonstrate the changes they have undergone in the course of time, and it is interesting to know that work is in progress on rural houses. Lord Raglan reports (*Folk-Lore*, September, 1946) that in parts of Monmouthshire every farmer lived in a cruck hall toward the end of the fifteenth century. About 1550 an entirely new type of house became general throughout the district. Its walls were of stone rubble and it was roofed with stone tiles. There were two rooms downstairs and two attics above. Cooking was done in an outside kitchen. Many of these houses were built round the older crucks. About 1600 the houses changed again, and usually had three rooms on each floor. This fashion lasted until about 1670, when there came in a kind of house more like the modern in plan.

5. *Folk-culture and the Present.*

Writers have held and still hold different opinions about whether folk-culture has anything to do with the present day, or whether it is by its nature restricted to the past. The answer may depend largely on our personal predilections. Many English folklorists have been particularly interested in survivals, and in those social groups who have been called ' rustics ' and ' yokels.' One of the French schools speaks frequently of ' pre-machinist ' culture, and this point of view might certainly appear a reasonable one to those who are making collections to illustrate the material

culture of the folk. The test of what constitutes folk-lore for Dr. Louis C. Jones in America is ' Do I want to know about the 18th century ? ' (*Folk-lore Institute of America*, 1946). On the other hand, very active studies of present conditions are being made in several European countries, and Professor E. O. James suggests (*Man*, May 1948) that we should carefully investigate ' the part played by customs, beliefs, institutions, and sanctions in the actual life of a community and its structural solidarity and continuity.'

These differences of outlook are so important that I must give a few minutes to them, even in the course of a very superficial and generalised address. It may be well to say at once that I consider the study of the present to be a source of great potential profit and a valuable aid to our studies of the past. Even if folk-lore were thought to consist only of superstitious beliefs in such things as ghosts, witchcraft, and amulets, there would be plenty of material for us to study, and we should not have to seek out remote country districts to find it ; the large cities offer us a rich enough field. The contents of the human mind may change, but not its nature, and the non-rational aspect of it is always ready to make its contributions. It would be of considerable interest to collect examples, which occur almost every day, of such things as the importance of the unusual, or of the results of anxiety and uncertainty.

Moreover, the present is far from being devoid of interest to the student of the folk-tale. While the late President Roosevelt was still alive, many stories about him circulated in the United States by way of mouth, and most of us in this country have been conscious at one time or another of the swarms of little quips and ancedotes which have never been printed, and which travel freely up and down the country, often keeping themselves to their particular social habitat. It would be worth while collecting them, comparing them with the tales of antiquity, and studying the mechanism of their distribution. Then, too, there are stories, some of which may gratify a common wish, such as the rumours of the abortive German attempt to invade England during the last war, or the passage through this country of Russian troops in the first war, while others, like the accounts of German plywood tanks, appear to be deliberately spread for political purposes.

Since our conduct is controlled by what we really believe in the core of our being, stories have a practical importance in modern life ; they form a large part of the stock-in-trade of the propagandist. We all know the short jocular story intended to belittle a political or personal opponent. Fortunately there are more sides to the subject than this ignoble one, and they may still throw light on political problems. A friend of Montrose once said that if he could write all a nation's ballads he would not care who made the laws, and Sir John Squire recently stated (*Illustrated London News*, 17/4/1948, p. 432) that democracy ' cannot be imposed upon a nation with incompatible traditions and nursery-tales.' It would, indeed, be hard to over-estimate the value of all such things which mould the sentiments and colour the outlook of each new generation, and it would be both interesting and useful to study the cinematograph shows, which now saturate the minds of our youth, and compare them with the old fire-side stories which they have largely replaced.

And may I suggest, as I have already done elsewhere, that modern folk-lore should be of interest to the churches. We hear frequent regrets at the small attendances at Sunday services, compared with those of fifty or sixty years ago. I doubt whether this has much to do with social changes, or with shorter or longer services. It is probably connected much more closely with changes in fundamental beliefs. Has there been any thorough recent study of what average men and women, i.e. the folk, really believe about the nature of their souls ?

One of the principal reasons for studying the present is that we can actually watch living processes and see how things happen. The two great wars provided many instances of strain and fatigue that might have much to tell us about how some stories originate. During the great retreat from Mons, troops marched almost to the limit of their endurance, and it is recorded that many of them thought they saw lights ahead of welcoming villages where there would be rest and refreshment. More recently a South African native soldier escaped from Tobruk (*South African Outlook*, 1/10/1945, p. 151), and tried to make his way across the desert to our army. He suffered greatly from thirst and was nearly exhausted. When in this condition everything appeared small ; a man looked about the size of a fowl. We heard of sailors, who, after spending days or even weeks in open boats, had visions of relief ships, which appeared to be visible to several members of a crew. On one occasion, a steersman sitting at the tiller saw a glass of beer float quietly in front of him and stretched out his hand to it. It would be well if some one would collect and publish accounts of such experiences ; there must be many to be had. In the past, also, men suffered from extreme fatigue when returning from distant fairs, or when engaged in winter on the hills, from hunger following bad harvests, especially in the spring or early summer before the new season's resources

were ready, and from various sicknesses. Any of these might give rise to hallucinations, which would be related to current beliefs, but there is need for further thought before we decide to what extent the relation would be one of cause or effect. There may be some connection between the spring fast and fairy visions in early May, and between the full barns and October brew and those of All Hallowtide. Folk experiences should offer an attractive field of investigation to the psychologists.

Again, it is by present-day studies that we can know the folk well and share, at least for a time, in their experiences. Otherwise all sorts of practical details will escape us. A little while ago, I realised that I had forgotten from which side a cow should be milked in this country. I knew that in Africa some tribes milk from one side, and some from the other, and I believe there are local differences in the Faeroes and Iceland. It gave me a little gratification to find subsequently that there were other folklorists equally unenlightened. Enquiry in my own district of eastern Montgomeryshire caused a good deal of amusement that I did not know that any common-sense person would always milk from the right, or off, side. This I understand is the rule in the Scottish Highlands, and in photographs from Gudbrandsdal in Norway the milkers also observe it; but Mr. T. D. Atkinson (*Local Style in English Architecture*, p. 4) quotes from *The Times*, 21/9/1938, '. . . in Ayrshire it is, it appears, the custom to milk from the near side.' I should like to see a map showing in which districts people milk from the right and those where they milk from the left.

There must, of course, be many other local characteristics of this kind. Lord Raglan, for instance, says that in one half of Monmouthshire thatching is done with the ears of the straw upward, and in the other half with the ears pointing downward (*Folk-Lore*, 1946, p. 102); in South Africa Basuto thatching is similarly distinguished from Zulu work.

A warm sympathy with the people we study is of further importance. We must avoid all trace of the *de hant en bas* attitude that was formerly too common among some folklorists. Country people are not yokels or inferiors. Dr. Johnson set us an example of a riper wisdom and of greater courtesy. He describes a chance meeting with a girl as he was travelling through the Highlands. 'We knew that the girls of the Highlands are all gentlewomen; and treated her with great respect, which she received as customary and due, and was neither elated by it, nor confused, but repaid my civilities without embarrassment, and told me how I honoured her country by coming to survey it.'

If we know the folk intimately, we are much better able to assess the value of what we collect. It would be wrong to interpret every statement in the same spirit. Sometimes a story may refer definitely to something that has happened or is thought to have happened; but sometimes an informant is speaking jocularly or figuratively. As a boy I often heard on a frosty morning that Jack Frost had been busy covering the pools with ice and decorating the window-panes with crystal patterns; and when it was snowing, the old woman was feathering her goose. Miss Trevelyan (*Folk Lore and Folk Stories of Wales*, 1909, p. 118) wrote, 'Among the mountains they say when a thick mist is rising, "Old Nick or Andras is boiling his supper," or "washing his feet," or "brewing," or "making his fire," or "putting out his fire."' We have nearly all of us heard of the man who was put in the moon because he chopped sticks on a Sunday. It is unlikely that anyone believed in this man, or in the old woman and her goose. I have mentioned them here because they remind us of problems that are engaging the attention of such Swedish investigators as Professor C. W. von Sydow and Dr. Albert Eskeröd. These writers urge us to study the actual work and feelings of the people in the harvest-fields, and at other times. It is suggested that the great wealth of harvest customs recorded by Mannhardt, Frazer, and others are not survivals of old fertility cults or of beliefs in vegetation spirits, but arise naturally out of recent conditions, some of them being due to the spirit of competition, or to jocular intents, while the custom of leaving a little corn in the field may be due simply to what Dr. Eskeröd (*Årets Äring*) calls the 'magic of continuance,' which finds expression in our country by a dislike of spending the last coin out of one's purse, and of completely cleaning out the old bread oven before the fire is lit for the next baking. Whether the Swedish scholars are right or wrong, they have issued a challenge that will have to be taken up; it will certainly not be adequately met by an undignified silence. The problem should recommend itself to students trained in psychology, in the methods of social anthropology, and in the practical details of folk-life. Can our mediaeval historians tell us what the villagers they study thought about these things?

I should like to mention just one other instance which shows the value of friendship with the people. Robin Flower has left us beautiful descriptions of the old Irish storytellers, which are imbued with respect and enlivened by that understanding which comes from intimate knowledge of their lives. One is of special interest because of what it tells us about the way in which modern

conditions are affecting men's minds even on a small island off the west coast of Eire (*Western Island*, p. 70). One of the islanders said to him, ' It was only the other day that I had all the old tales in my mind, and I could have spent the night telling them to you without a word out of its place in any tale. But now I couldn't tell a tale of them.' He went on to say, ' the little tales one after another, day after day, in the books and the newspapers, have driven the old stories out of my head.' We are all of us conscious of the unending succession of little routine tasks and of unconnected snippets of information that afflict the mind like a swarm of midges, and make almost impossible the consecutive thought which is necessary for any serious work. Our memories of the quiet, seemingly endless days of childhood, spent in the fields and woods and by the banks of streams, help us to much understanding of the folk mind.

6. *The Ecology of Folk-lore.*

Out of loyalty to our subject I sometimes venture to criticise the work being done in England, but it is very easy to under-estimate Britain's total contribution. Our contribution to the knowledge of dance and song is widely appreciated, and these subjects are in the hands of an enthusiastic and active society. The Place-name Society publishes its scholarly volumes at intervals, and the Folk-Lore Society has in recent years done good service by issuing a series of books describing British calendar customs. In a sense, however, the publication of the latter volumes marks the end of an epoch in our studies, and perhaps the beginning of a new one. They have done much to gather in the harvest, though there is still more to be gathered. It remains for this and succeeding generations of British scholars to do the threshing, winnowing, milling, and baking, and also to plough the fields again for new crops.

Much work has been carried out in Europe and America on the folk-tale. There have, as is well known, been several attempts to classify the different kinds, to study the occasions on which they are told, to appreciate the art of the story-teller, to investigate the different ways in which the various types of stories spread, the conditions which determine whether they gain lodgement in a new environment, and their distributions together with those of their variants. English folklorists have taken little part in all this in recent times. Mr. Kenneth Jackson writes, ' . . . since the time of the younger Krohn they have stagnated in a backwater ; it is curious how cut off from the main stream of world development much English folk-lore research has been in the last thirty years, . . .' (*Folk-Lore*, September, 1947, p. 340).

Much the same could be said of other branches of English work. There seems to be only one material trait of which we know all the local varieties, the methods of production, and the distribution of the variants. That knowledge we owe to Mr. James Hornell's study of the coracle. There are almost limitless opportunities for the student who likes travelling in the country. I know of about forty kinds of bill-hooks characteristic of different districts, and there are probably more. We could employ a large team o. young scholars to find out the reasons for the different kinds of bill-hooks, and to follow the boundaries of their areas of distribution, noting where and why there is a change from one kind to another. Similar work is needed on very many other objects, such as scythe handles, rope-twisters, eel-spears, peat spades, boats, fishing nets, clogs, and so forth. The work would probably throw much light on the details of local farming and on local history. Although there is ample employment for those whose inclinations are for the library, there are many things that we can only investigate out-of-doors, working from farm to farm.

In the present connection I must content myself with a brief reference to one other subject, and that shall be houses. There are many good books dealing with English houses, but there is still very much research to be done on the evolution and distribution of local styles, on the materials used, and on the interior arrangements. The French school of human geographers, in the work of such men as Brunhes, Arbos, Demangeon, Musset, etc., has given a valuable lead in this direction, and it is fortunately possible to report that interesting work is now going forward in England ; we are to hear a description of the field-work that is being directed from the University of Manchester.

In his Anniversary Address, published in *The Antiquaries Journal*, 1926, Sir Cyril Fox said, '. . . there are variations in plan in various parts of England and Wales in small sixteenth and early seventeenth century houses reflecting similar economic levels. In my own limited experience lay-out is surprisingly uniform in yeomen's houses in a given region, at a given time ; what then is the distribution of such variations ? The answer should provide us with a clue to ancient cultural boundaries in Britain.' Before we find the answer, we shall have to draw many plans and maps, and learn a good deal of history.

It would be fitting to remind ourselves at this point of the fine examples which other countries are setting us. I can only mention in passing the interesting reports issued in Norway by such scholars as Jan Petersen and Thv. Krohn-Hansen, the splendid volumes

published in Sweden, such as Professor Gerda Boethius' *Den Nordiska Timmerbyggnadskonsten* (1927), *Hallar, Tempel och Stavkyrkor* (1931), Dr. Eric Lundborg's *Herremannens Bostad* (1935), and Professor Sigurd Erixon's monumental work, *Svensk Byggnads Kultur* (1947), the exemplary initiative of the Irish Folk-Lore Commission, and the inspiring work which the Musée des Arts et Traditions Populaires is directing on a national scale from Paris.

The French school seems to start from the conception of the rural house as a mechanism designed to provide human beings, animals, equipment, and harvested crops with suitable conditions of heat, light, and humidity, and with suitable arrangements for the necessary occupations. The house and its outbuildings are the outer shell about a particular way of life. There must be rooms for cooking, eating, sleeping, dairying, brewing, weaving, curing, storing, etc., and these are influenced by geographical, historical and social factors. At various times in history, there have been changes in the way of life ; new crops have required new methods of cultivation and new methods of storage and treatment. Sheep-farming has at times spread at the cost of arable cultivation, or into districts where there had been little agriculture. Recently the concentration on milk production has changed the life on many farms. If such changes of occupation do not take place too rapidly, the house and its accessory buildings will be adapted to meet the new requirements, with, of course, a certain amount of lag. The development of modern machinery has in many regions thrown the structure and arrangement of the buildings seriously out of conformity with farming needs, and this raises extremely interesting problems for our architects and country planners.

A word of caution may not be out of place in connection with this problem of relating houses to their environment. It seems natural that, if there are good supplies of building material near at hand, they should be used, but it does not follow that they will be. Professor Dauzat points out that in parts of Normandy, as in the Caen district, there is very little timber, but the houses are of wood, whereas in the well wooded bocage they are of stone (*Le Village et le Paysan de France*) ; nor is the relation between the pitch of the roof and the amount of rainfall or snowfall as constant as some writers might lead us to think. History and tradition clearly influence such matters.

Folklorists, who refuse to restrict their studies to the past, and who want to know the folk as they live and work to-day, are learning to co-operate with sociologists. American scholars have studied new settlements and the part played by the church, school, smithy, and local store in strengthening group solidarity. In a paper published in *Le Mois d'Ethnographie Française* (March, 1948), Mlle Edith Fel of the Ethiographical Museum in Budapest gives a very interesting account of recent research in Hungary. She says that all the artificial divisions between material culture, oral traditions, etc., are breaking down, and that workers from museums are adopting the sociological and functional points of view. The new outlook is associated with more direct observation, often by teams of specialists, among whom may be demographers, statisticians, medical men, students of law, and so on.

Britain can, of course, show much interesting work. The Le Play Society continues its activities, and there are good books on village life and on the work of farmers and craftsmen ; but we are brought face to face again with luxuriant inaccessibility and there is a lack of co-ordination between one department of research and another. We need an active lead from the Folk-Lore Society or some other body to bring together many excellent but isolated activities.

It has, I hope, become clear that the modern student of folk-life has as much need of a good general training in the subject as historians, botanists, or chemists in their special fields. In 1896, Sir Laurence Gomme drew our attention to this, and pointed out the unequal value of the data at our disposal, which, he said, are ' seldom if ever the result of trained observation, and they are often mixed up with theories as to their origin and relationship to modern society and modern religious beliefs.' He recognised that a given custom might have (a) radical elements and (b) divergent elements which are more changeable. Several members of the modern Swedish school appear to be thinking along similar lines, and they are producing thought provoking work.

Anyone who has visited some of the museums of this country must be conscious of how thoroughly the objects have been lifted out of their contexts, and how little has been done to preserve all the knowledge about the making and using of every tool, the materials that have been employed and the sentiments with which it was formerly associated. Mrs. M. M. Banks mentioned this question of associated sentiments in *Folk-Lore* (March, 1939), and it is one of much interest. She says that for the old people ' implements for the tilling of the earth were possessed of power ; the plough, sickle, cart, and in Scotland the barn and even the kiln where grain is dried were common in rites of divination, particularly at Hallow e'en . . .', and

that this was on account of their connection with the earth and its crops.

7. *General aims.*

I have indicated a few of the problems that face us and the need for much further scientific study in Britain; but even if all these tasks should be completed our work would not be finished. The final aim is to write a full, historical account of the folk-life of Europe, with all its changes and varieties as far as we can trace them through time and space. We must see Europe and the adjacent lands as a whole, even if we have to travel from India to Eire and out to Iceland and America. Many simple things, apparently completely at home in some quiet nook in this country have close relations distributed across two continents, and this may be true of a belief, a story, a custom, or an artifact. Even such very homely things as our sayings about white specks in the finger nails occur outside of Britain. How much we owe to a freedom of intercourse throughout mediaeval, catholic Europe, and how much we must ascribe to earlier migrations or diffusion, I am not qualified to say.

There are suggestive parallels between the cultures of Scandinavia and of the Alpine zone, as, for instance, the occurrence of the trumpet of wood or bark—the lur or alpenhorn. Must we think, as there seems some grounds for doing, that an ancient culture was once widely distributed over Europe, and that it was pushed away into a northern and a southern province by a later intrusion along Central Europe. If so, with what historical or archaeological circumstances must we associate the change. Or again, can we still trace any characteristics of regional folk-cultures back to the diffusion of the megalithic monuments, or to the spread of the Aryan-speaking peoples? These questions again emphasise the need for close contacts with historians and prehistorians. Several of our predecessors in folk-studies have tried to point out ways in which folk-lore could help history; I am, at present, much more concerned with the assistance which I hope the historians will give to us as students of folk-life—we require a very great deal.

The pollen analysts have reconstructed for us much of the post-glacial plant history of Europe. They have shown us the stunted arctic flora moving up after the retreat of the ice sheets, followed by the birch and coniferous trees, which in turn yielded place to the mixed broad leaf forests. Successive plant waves have flowed over the lower and richer parts of Europe, breaking against the mountain slopes, sending tongues up the broader valleys, and sometimes surrounding mountainous massifs, in which the immigrants brought by earlier waves hold their ground. There has been advance and retreat, intermingling of elements, and innumerable adaptations to new conditions. It may be that some day we may be able to write an equally interesting account of European culture-history.

8. *Practical Requirements.*

If Britain is to make its due contribution to the study of European folk-culture certain developments in this country are essential. It would be out of place to discuss them in detail in this address, but I must make a few brief references to them.

First, it is necessary that our subject should be supplied with much more copious periodical literature. There should be a journal which will do for folk-culture what the French publication, *L'Anthropologie*, does for anthropology and archaeology, i.e. supply reviews of all important publications and information about work being done in this and other countries. The need could be met in one of two ways. Either the Folk-Lore Society should increase the size and extend the scope of its journal, *Folk-Lore*, or a new publication should be devoted to material culture. There are many museums, perhaps to be numbered in hundreds, in Britain which are collecting objects of folk-culture. The curators and their correspondents scattered over the surrounding districts need help and many of them would subscribe to the kind of publication which I have in mind.

Secondly, it is desirable that there should be a central archive, where information could be stored and made available. There are excellent examples of these in practically every one of the neighbouring European countries, and in Eire; and perhaps before long Wales will have one. The information would be obtained from observers and correspondents well distributed over the country, possibly in answer to questionnaires sent out from the central archives. The organisations in Oslo, Stockholm, Uppsala, Lund, Paris, and Dublin are standing reproaches to England in the wonderful opportunities which they offer to the serious student. We have been asked by Paris at least to collect on sheets of a standard size simple, scale drawings of the objects scattered through our Museums, and to send copies of them to the European centres, in exchange for similar drawings. Such work could possibly be done by the Museums' Association, but it would be preferable that it should be in the hands of the Folk-Lore Society, in order that there should be no artificial cleavage between the material and non-material sides of culture. I need scarcely say that in the building up of a national body of information we should need

the help of scholars whose work lies in the libraries, as well as of those who can carry out investigations out of doors.

Thirdly, there should be friendly discussions and as far as possible active co-operation between the various societies interested in folk-culture. This would not in any way impair the complete independence of any society, but it would undoubtedly be for the benefit of all. A welcome step might be a few days conference between the English Folk Dance and Song Society, the English Place-name Society, and the Folk-Lore Society. The close co-operation between similar societies in the preparation of a national atlas in Upsala, and the happy results flowing from it, should be sufficient encouragement for us.

In connection with this problem of co-operation. I must once more stress the necessity for joint work with historians and archaeologists. We need their help in almost every branch of our work, whether we are studying customs and beliefs, houses, dress, music, food, agriculture, or children's games.

Finally, there is the most urgent need for workers who have received a thorough training in the subject. The study of folk-life has become many sided, and a vast amount of important work has been done and is now being carried on in other countries. It will require formal training to equip future students with that knowledge of past achievements, present aims, and technical methods which they will need, in order to make serious contributions of new knowledge on the part of Britain to European science. Other countries such as Sweden, Hungary, and France, to mention three practically at random—can find numbers of students suitably prepared to go into the field every year and carry out important investigations. Where should we find them in England?

The present backwardness of Britain compared with most other civilised countries is unquestionably due, to a great extent, to the failure of the universities to provide the necessary training. There are University chairs in various branches of folk-life in Norway, Sweden, Denmark, France, Hungary, Eire, and South America, and possibly elsewhere. In Britain several universities are prepared to study the peoples of Africa, the tribes of Melanesia, or the cultures of Asia. Why is it that no university can show enough interest in our own national life and traditions to assist the new generation of students to bring us back to our rightful place in the main stream of European scholarship? We might well take to heart the words of R. B. Perry (*Folk-lore Institute of America*, 1946, Part II, p. 15), 'The chief source of spiritual nourishment for any nation must be its own past perpetually rediscovered and renewed.'

SECTION I.—PHYSIOLOGY

RECENT ADVANCES IN COLOUR VISION

ADDRESS BY

PROF. H. HARTRIDGE, F.R.S.

PRESIDENT OF THE SECTION

CONTENTS

SECTION		PAGE
1	INTRODUCTION	243
2	THE POLYCHROMATIC THEORY	244
3	HUE DISCRIMINATION	245
4	TRISTIMULUS SPECTRAL MIXTURE	245
5	THE RETINAL DIRECTION EFFECT	247
6	PERIPHERAL VISION AND REDUCED FOVEAL VISION	247
7	THE CONSTANCY OF WHITE	248
8	THE EFFECTS OF LIGHT INTENSITY, ADAPTATION AND VISUAL ANGLE ON FOVEAL SPECTRAL MIXTURE	248
9	SELECTIVE ADAPTATION	249
10	SATURATION DISCRIMINATION	249
11	THE ANTICHROMATIC RESPONSES, THE FIXATION POINTS AND THE SUBJECTIVE COLOURS	250
12	SOME OTHER RECEPTOR ARRANGEMENTS	251
	SUMMARY	253

SECTION 1

INTRODUCTION

MANY theories of colour vision have been suggested from time to time. Most of them have received little support, but two have been exceptions in this respect, namely, Young's three-colour theory and Hering's four-colour theory. The former is in apparent conformity with colour mixture and with colour deficiency data, while the latter is superficially in agreement with other important aspects of human colour vision. The polychromatic theory to be dealt with in this address is the outcome of an attempt to combine together the good features of both these older theories.

According to Young's theory human colour vision is provided by a tricolour unit. On the other hand, according to Hering's theory it is provided by two units : a yellow - blue unit and a red - bluegreen - red unit. The polychromatic theory proposed by the author adopts the tricolour unit as its principal agent and the yellow - blue and red - bluegreen - red units as its subsidiary agents. Thus human colour vision is nearly trichromatic but not quite, because in addition to the tricolour unit there are also present the two additional units just mentioned.

Here then is an outline of the polychromatic theory.

Polychromatic theories have been advanced by Wundt, by Edridge-Green, and in a modified form by Shaxby. Granit's modulators also form, in some animals, what amount to a polychromatic series. The polychromatic theory advanced by the author differs from all these in important respects, and it is not proposed to deal further with them here, but instead to describe briefly the circumstances which lead to the development of this particular theory.

Until a few years ago experimental work appeared to support unequivocally the three-colour theory of Thomas Young. When the author first observed the change of yellow to pale grey or white, and of blue to dark grey or black, which play so essential a part in the antichromatic responses, he endeavoured, apparently with success, to account for them on this classic theory. But further facts then came to light incompatible with that theory. These facts were : (1) the change in the shape of the luminosity curve with reduction of light intensity, and the development of a notch (Sloan, 1928) ; (2) the corresponding change in the shape of the luminosity curve with reduction of visual angle (Willmer and Wright, 1945) ; (3) the finding by the author (1947)

of more fixation points in the fovea than three ; (4) the finding by the author of more specific colours than three, as the result of applying microstimulation to the retina in the presence of suitable conditioning stimuli. These results, incompatible with the three-colour theory, led to a re-examination of the whole subject of colour perception.

The outcome of that survey convinced the author that, under average conditions of lighting, adaptation and field size, the three-colour theory is a useful approximation so far as foveal vision is concerned. It is the truth but not the whole truth because it is not in accord with a large mass of evidence, much of which has been obtained recently, partly by using improvements on older methods, such as the mixture of spectral colours by means of the Wright spectroscope, and partly by the development of entirely new methods—for example, the Stiles and Crawford technique. But much older work was also found at variance with the three-colour theory. When all this evidence has been taken into account it would not be unfair to sum up by stating that there is hardly a single phase of human colour vision which does not support a polychromatic theory more strongly than it does one based only on three colours.

Section 2

The Polychromatic Theory

The polychromatic theory postulates the existence of two subsidiary visual units in addition to the tricolour unit of Young's theory. One of these, the Y - B unit, has receptors with response curves having crests in the yellow and in the blue parts of the spectrum. The other unit—the R - BG - R unit, also comprises two types of receptors and these have response curves with crests in the red and in the bluegreen part of the spectrum, but the former have in addition secondary curves in the extreme violet part of the spectrum. This fact is indicated by the duplication of R in the title of the unit.

When the fovea is being used in normal colour vision all three units are in action. When a more peripheral part of the retina is in use the Y - B unit alone provides colour vision. The fovea at very high light intensities also employs this unit alone, whereas at low intensities or small visual angles the R - BG - R unit functions alone. With white stimuli, all the constituent receptors of the functioning units receive adequate stimulation. When, on the other hand, the objects under examination are coloured, then the receptors which are stimulated are those which have response curves in the corresponding part or parts of the spectrum, and which belong to functioning units. The following example may make this clearer : suppose the ray incident on the retina to be red of 0·65μ, then the stimulated receptors are the long wavelength receptor of the tricolour unit, the red receptor of the R - BG - R unit and the yellow receptor of the Y - B unit. If the ray which falls on the fovea is of medium light intensity all three units will be potentially in action and the sensation aroused by their combined actions will be a somewhat orange-red.

At very high intensities, however, as stated above, the only active unit is the Y - B one, and in consequence the sensation aroused by the stimulus of wavelength 0·65μ will be yellow. At low intensities the only active unit is the R - BG - R one, and the sensation aroused will consequently be a purplish crimson, since this is the hue produced by the activity of the red receptor of this unit which, as stated above, has response curves both in the red and in the violet parts of the spectrum. These theoretical conclusions agree with experiment.

These three units together comprise seven different types of receptor and these have eight response curves, the spectral positions of which are indicated in Table 1.

Table 1

Visual Unit	Position of Receptor in the Spectrum	Probable Wavelength of crest of Response Curve
Tricolour	Orange	0·610
,,	Green	0·545
,,	Indigo	0·450
Y - B	Yellow	0·575
,,	Blue	0·473
R - BG - R	Red and Violet	0·670 and 0·360
,,	Bluegreen	0·495

The wavelengths shown in the last column are approximate only.

When white light falls on the retina it stimulates all receptors of active units. Thus at the fovea under medium light intensities all seven receptors will be active, at high intensities the yellow and the blue receptors only, at low intensities the red and the bluegreen receptors only. At the dichromatic zone of the periphery of the retina the yellow and the blue receptors are those which are stimulated, because the Y - B unit is the only one which is potentially active. This accounts for the large sizes of the yellow or blue fields in comparison with those of red and green. It is clear therefore that according to the present polychromatic theory all seven types of

receptor are in use only at medium light intensities at the fovea and the parafovea. At other intensities and in the periphery of the retina a simpler receptor arrangement is in use. As the visual angle is reduced, first the Y - B unit becomes inactive, then the tricolour unit, finally leaving the R - BG - R unit alone in action. The author has produced evidence that these changes are not limited to the foveal centre but take place in all parts of the retina where all the three units are normally in action.

Section 3

Hue Discrimination

It will be remembered that there are two classes of subject who are able to pass successfully the ordinary tests for colour blindness; these are the normal trichromats and the anomalous trichromats. The latter are subdivided into two classes according as they require more red or more green, than the normal sighted, in order that a red - green mixture shall match a given yellow. Those who require more red and are therefore somewhat red-blind are called protanomalous, since they approximate to the completely red-blind or protanopic. Those who require more green and are therefore somewhat green-blind are called deuteranomalous, since they approximate to the deuteranopic subject.

There are two varieties of protanomalous trichromat: a primitive type and a more advanced type. The hue discrimination curve of the former consists of two U-shaped parts, having troughs at about $0{\cdot}49\mu$ and $0{\cdot}59\mu$. To account for this curve three types of receptor are required, namely: in the long, medium and short wave region of the spectrum. The hue discrimination curve of the better type of protanomalous subject, such as Wright's observer A, shows improvement in the green part of the spectrum. To account for this improvement an additional receptor is required, probably in the bluegreen part of the spectrum. Investigation shows that an alteration of position, or a change of width, of the response curve of one of the three receptors mentioned above, does not bring about the improvement shown on comparing the curves.

The colour vision of the normal subject as found by Pitt and Wright (1934) shows improvement at about $0{\cdot}44\mu$ over that possessed by observer A, and there is a second region of improvement near the orange part of the spectrum. To account for these improvements two additional types of receptors are required, in the blue and the yellow. Finally, some normal-sighted observers, such as Steindler (1906), Jones (1917), Laurens and Hamilton (1923), appear to have better hue discrimination still, particularly in the red part of the spectrum. This calls for an additional type of receptor.

Calculations of the hue discrimination curve of normal-sighted subjects have been made by Helmholtz (1896), Judd (1932), Stiles (1946), and others, on the basis of the three-colour theory. These calculated curves are far from being identical in shape with the experimental curves obtained with normal-sighted, protanomalous (including Wright's observer A) and deuteranomalous observers, as should be the case, because according to the three-colour theory all these three classes are 'trichromats.' Thus the three-colour theory fails to give a satisfactory account of the hue discrimination of these subjects. The polychromatic theory, on the other hand, postulates three types of receptor for the more primitive protanomalous subject, four types for the more advanced type, probably five types for the deuteranomalous and seven types for subjects with normal colour vision.

Section 4

Tristimulus Spectral Mixture

It is well known that when the different parts of the spectrum are matched using as stimuli a red of $0{\cdot}65\mu$, a green of $0{\cdot}53\mu$ and a blue of $0{\cdot}46\mu$, trichromats usually find that most of the spectral colours are more saturated than the mixtures. These differences of saturation are noticeable in four main spectral regions: in the red near the long wave end of the spectrum, in the yellow, in the bluegreen, and in the violet near the short wave end of the spectrum.

Trichromats differ markedly from one another in their ability to match the rays corresponding to these spectral regions with the three matching stimuli. These differences, so far as the yellow and bluegreen are concerned, are summarised in Table 2.

Table 2

Type of Subject	Negative Coefficients	
	Red Stimulus in Bluegreen part of Spectrum	Blue Stimulus in Yellow part of Spectrum
Normal protanomalous . .	Nil	Nil
Improved protanomalous . .	2–3 %	Nil
Normal fovea .	10–12 %	3–5 %
Normal parafovea	10–12 %	10–12 %
Deuteranomalous .	Over 12 %	Under 3 %

In the table (page 245) the various classes of trichromat are arranged in order, the more primitive protanomalous subject first because the differences in saturation of the monochromatic spectral colours and the mixed colours are very small, or absent. Then comes the improved kind of protanomalous subject such as Wright's observer A ; then the fovea of the normal-sighted subject ; then the parafovea of the normal-sighted subject ; and lastly, the deuteranomalous subject to whom the bluegreen spectral colours are far more saturated than the mixture of the green $0 \cdot 53\mu$ and the blue $0 \cdot 46\mu$.

The differences in saturation between the monochromatic and the mixed colours are accounted for on the three-colour theory by supposing that the three-receptor processes have poor spectral selectivity, that is, that their response curves spread over much of the spectrum. Thus the blue response mechanism is sensitive to almost all greenish rays as well as to blue ones ; the green response mechanism is senstive to almost all rays ; and the red response mechanism is sensitive to almost all green rays, as well as to yellow, to orange and to red ones. In consequence monochromatic yellow light, which acts as a stimulus to both the red and the green response mechanisms, but not to the blue ones, appears, according to this hypothesis, to be more saturated than a red and green mixture which stimulates not only the red and the green mechanisms but the blue ones as well.

In support of this hypothesis McAdam (1947) has pointed out that when reproduced by a three-colour photographic process spectral yellow is more saturated than a red-green mixture. In this case there can be no doubt that the wide overlap of the response curves of the three colour selecting filters is responsible for the observed differences of saturation.

Suppose that this argument be accepted in the case of human colour vision, then it is found to lead to the following conclusion : that subjects who do not find differences of saturation between monochromatic and mixed colours, that is, subjects who are protanomalous trichromats, either have receptors of narrower response, that is of greater selectivity, than other trichromats, or that their saturation discrimination is poor, so that they make matches which would be unacceptable to normal subjects who are better in this respect. Now Chapanis (1944) has shown that the latter is not true, because so far as the yellow region of the spectrum is concerned the protanomalous possess better saturation discrimination than the normal-sighted do. It is therefore concluded that their receptors have better selectivity because the response curves of these receptors do not overlap as much as they do in the normal-sighted. On comparing similarly protanomalous with deuteranomalous trichromats it is concluded that the former have receptors with much greater selectivity than those of the latter. Now receptor selectivity plays a fundamental part in colour vision because poor selectivity must cause all colours to look much alike, so that no colour approaches in saturation that which would be produced by the stimulation of a single type of receptor only. *Vice versa*, high receptor selectivity must cause colours to appear to possess a high degree of saturation. On these grounds, of all the types of subject with trichromatic vision mentioned in Table 2 above, the protanomalous must have the best colour vision and the deuteranomalous the worst. The normal-sighted come in between, with the fovea superior to the parafovea. Now these conclusions are completely at variance with the facts, for the protanomalous are little better or worse than the deuteranomalous, and both are greatly inferior to the normal-sighted, in whom the parafovea is superior to the fovea.

According to the polychromatic theory the monochromatic colours have superior saturation to the mixed colours because the former stimulate an additional receptor more strongly than do the latter. Thus to the normal-sighted subject spectral yellow is more saturated than a red - green mixture, because the former stimulates yellow receptors strongly and red ones and green ones feebly. On the contrary, the red - green mixture stimulates the red and green receptors strongly but the yellow ones feebly. In a similar manner enhanced saturation of the monochromatic spectral colours in the extreme red is caused by the additional type of receptor which operates in this part of the spectrum. Additional bluegreen receptors improve saturation in the bluegreen region, and additional violet receptors in like manner improve short-wave saturation. Since, to the primitive type of protanomalous subject, the single spectral colours and the spectral mixtures which match them are alike in saturation, no additional receptors are present, and their colour vision is mediated by the fundamental tricolour unit alone. Thus of all so-called trichromats they should have the most inferior colour perception. The improved type of protanomalous subject, to whom the bluegreen rays are more saturated than are blue and green mixtures has the additional bluegreen type of receptor according to the polychromatic theory, and therefore is superior to the more primitive protanomalous subject in this respect. The position of the deuteranomalous subject is not entirely clear, but according to present evidence he possesses both the tricolour unit and the bluegreen

and possibly also the red receptors of the R - BG - R unit. But the former is outweighed by the latter so that he approximates to a dichromat, and this accounts for his inferior colour vision. For normal foveal vision seven types of receptor are required, the three-colour unit and the four additional receptors of the Y - B and the R - BG - R unit, the former strongly and the two latter, particularly the Y - B unit, feebly. At the parafovea, so far as present evidence goes, the same seven types of receptor are present but the additional ones hold a more prominent position, so that they play more nearly the same part as that played by the tricolour unit.

According to the polychromatic theory, therefore, both the protanomalous and the deuteranomalous have inferior colour vision to the normal-sighted subject ; and in the latter, the parafovea has superior colour vision to the fovea, and these deductions are found to be in harmony with the results of experiment.

Section 5

The Retinal Direction Effect

When a narrow pencil of monochromatic light traversed the pupil horizontally, Stiles (1937) found changes in brightness, hue and saturation. The author (1947) has pointed out that the magnitude of the brightness effect for yellow rays is substantially less than it is either for red or for green rays. This makes it unlikely that yellow rays stimulate red and green receptors alone, as is postulated by the three-colour theory. It is more probable that there are specific yellow receptors having a different intensity direction effect from that of the red or green receptors. The other aspects of the retinal effects on intensity can be accounted for on the three-colour theory.

Stiles (1937) found that the variations of hue with wavelength are more complex than would be expected on the three-colour theory. On the three-colour theory there are only eight possible combinations, of which the two exhibiting the greatest variation with wavelength are red +, green −, blue +, or *vice versa* : red −, green +, and blue −, that is a single crest in the green with lower values in the red and in the blue, or a single trough in the green with higher values in the red and the blue. Now Stiles obtained on the temporal side of the pupil a graph exhibiting two troughs and one crest, whereas on the nasal side of the pupil the graph showed more detailed changes still, namely, two troughs and two crests. In order to account for the former a minimum of four types of receptor are required and in order to account for the latter a minimum of five types. Unfortunately Stiles has not investigated the phenomenon with sufficient detail for a more precise estimate to be made of the number of types of receptor required, but there would seem to be no difficulty in doing this.

With regard to the third retinal direction effect, namely, on saturation, Stiles has not given any details of this beyond mentioning the fact that such variations exist, so that no statement is possible at the moment as to its value in the elucidation of the problems of colour vision. The effects on brightness and hue may be summarised as follows : the brightness effect requires at least four receptors, of which yellow must be one ; the hue effect requires at least five. Further study of the effects may show the necessity for more.

Section 6

Peripheral Vision and Reduced Foveal Vision

The term ' reduced foveal vision ' has been used by the author (1947) to denote the type of hue perception found at the fovea at low light intensities and at small visual angles. Reduction of intensity or visual angle results in the replacement of full colour vision, first by a form of dichromatism, and then, by colourless foveal vision. In the dichromatic stage colours are seen in terms of two primaries only, red and bluegreen, and mixtures of these with white, grey or black. The author attempted to account for this type of vision on Young's theory by supposing a type of linkage to occur between the green and the blue receptor pathways. But this supposition had to be abandoned when the changes in the shapes of the luminosity curves found by Sloan (1928) and Willmer and Wright (1945) were taken into account. During the changes just referred to, many colours, both spectral and mixed, undergo alterations in hue but there are four invariable colours : blue, bluegreen, yellow and red. The blue and the yellow are replaced by colourless shades of grey at an early stage of the change ; the bluegreen and red are similarly replaced by greys but at one of the last stages.

When foveal vision is gradually replaced by peripheral vision, colour perception becomes reduced until, as in the case of foveal vision, a colourless state is obtained. At an intermediate stage in this change dichromatic vision occurs in which colours are seen in terms of yellow and blue, and mixtures of these with white, grey or black. In this case, also, four invariable colours are found, which are blue, bluegreen, yellow and red, but whereas with reduced foveal vision the

yellow and the blue suffer early replacement and the bluegreen and red suffer later replacement by greys, in the case of peripheral vision the situation is reversed and it is the bluegreen and the red which undergo early changes and the blue and the yellow which undergo the late change. Attempts have been made to account for these changes in colour vision on Young's theory, by supposing that linking occurs between the red and the green receptor pathways. Thus the vision of the blue-yellow zone of the periphery is identified with the dichromatic vision of the deuteranopic subject in whom permanent linkage of these pathways is supposed to be present. But this supposition also is rendered untenable by an examination of the luminosity curves, because that of the dichromatic zone of the retinal periphery was discovered to have a crest at 0·59–0·60μ (von Kries, 1897). When his values were corrected for an equal energy spectrum by the author the crest of the luminosity curve shifted to a wavelength of about 0·58–0·59μ. Now the crest of the luminosity curve of the deuteranope, as found by Pitt (1944), occurs at 0·565μ. Thus the suggestion of linking between certain receptor pathways has to be abandoned. These difficulties introduced by the luminosity curves are not the only ones making the position of the three-colour theory untenable.

According to the polychromatic theory, with reduction of visual angle or lowering of light intensity, or both, the Y-B unit is the first to become inactive and this is followed by the tricolour unit. In consequence the R-BG-R unit is the only one in a state of activity. The notches in the luminosity curve observed by Sloan (1928) and by Willmer and Wright (1945) are due to the inactivity of the Y-B unit in the blue and in the yellow parts of the spectrum. On the other hand, when a more peripheral part of the retina is employed the first unit to become inactive is the R-BG-R, and this is followed by the tricolour unit. At this stage the only unit in action is the Y-B one, and this has the luminosity curve found by von Kries.

So far no mention has been made of the effects of increasing light intensity. The colour changes as found by Purdy (1931) strongly resemble those produced by using a peripheral part of the retina. If the illumination be sufficiently bright there is colourless foveal vision ; at a less intense illumination there is yellow-blue vision, which, according to the polychromatic theory, is due to the activity of the Y-B unit. Thus the polychromatic theory accounts for these phases of colour vision by postulating activity of certain visual units and the inactivity of others, and in this way accounts for their properties in a satisfactory manner.

Section 7

The Constancy of White

When identical pairs of coloured test objects are examined, one by the fovea and the other by the periphery of the same eye, most of them are found to differ, yet when white test objects are similarly examined no differences can be detected. When similar experiments are performed to test the effects of light intensity or of size of visual angle, coloured test objects are found to undergo marked differences, but white test objects similarly tested are found to undergo no observable change. This constancy of white is the more remarkable because deviations from white are so readily noticed.

Now according to the three-colour theory, the perception of white is due to the stimulation in a certain fixed ratio of all three receptor processes, so that the constancy of white proves that this ratio is the same for the periphery of the retina as it is for the fovea, and is the same at the fovea for high light intensities as for low ones, and for large visual angles as for small ones. The important colour changes which are found to occur under these different conditions make it imperative that there should be alterations in colour perception, and yet the constancy of white shows that they cannot occur so far as the three-colour theory is concerned.

While great difficulty is experienced on the three-colour theory no such difficulty faces the polychromatic theory, because it is the property of the three units, either separately or in combination, to respond to a white stimulus by means of a white sensation. Suppose, for sake of argument, that the colours orange, green, indigo and purple be examined (*a*) by the dichromatic zone of the retinal periphery where the Y-B unit is found in a pure state ; (*b*) by the dichromatic vision of the fovea at a small visual angle which is mediated by the R-BG-R unit ; then these colours will all be found to exhibit marked differences, when they are examined first by the one type of vision and then by the other. But white similarly tested will be found to undergo no change, because, as stated above, both the Y-B and the R-BG-R units respond to a white light stimulus with a white sensation.

Section 8

The Effects of Light Intensity, Adaptation and Visual Angle on Foveal Spectral Mixture.

Various factors have been found to affect the matches between monochromatic spectral colours and mixtures of spectral colours. Thus von Kries (1896) investigated the

effects of light intensity, Wright, the effects of adaptation (1936), and Hering (1893), Horner and Purslow (1947) and Shaxby (1947), the effects of visual angle on the match between yellow and a red - green mixture. These effects, which have recently been confirmed by the author, are summarised in Table 3.

TABLE 3

	Red - green mixture compared to pure Yellow
High intensity . .	Greener
Low ,, . .	Redder
Light adaptation .	Greener
Dark ,, . .	Redder
Large visual angle .	Greener
Small ,, ,, .	Redder

The three-colour theory, which postulates that yellow and a red - green mixture resemble one another in stimulating the red and the green receptors, finds it difficult, if not impossible, to account for these disturbances of colour matches. Attempts to account for them on the grounds of the selective absorption of the yellow pigment of the fovea or of the greater " rod value " of green are both found to fail. According to the polychromatic theory, on the other hand, there are independent receptors for red as well as for orange, for yellow and for green. The red ones, since they belong to the R - BG - R unit, play a more important part in foveal vision at low light intensities, at small visual angles and when adapted to low light intensities. Thus under these conditions the red component of the red - green mixture is accentuated and this disturbs the match with yellow.

SECTION 9

SELECTIVE ADAPTATION

Burch (1898 and 1900) concluded from fatigue experiments that the human retina contains four types of receptor : red, green, blue and violet. He was unable to obtain evidence for a fifth type of receptor, namely for yellow rays.

Allen (1908) after fatiguing the eye to rays of $0 \cdot 589\mu$ or of $0 \cdot 577\mu$ found that the rate of flicker was noticeably reduced both in the red and in the green but hardly at all between $0 \cdot 64\mu$ and $0 \cdot 58\mu$. This was held to be evidence that yellow rays are perceived owing to the stimulation of red and green receptors but not of specific yellow receptors.

Edridge-Green and Marshall (1909) after exposing the eye for a short time to a sodium lamp claimed that they found unmistakable evidence for separate yellow receptors. The author (1948) using yellow colour filters both monochromatic and dichromatic (red and green) of sharp spectral cut-off and equal visual appearance, found on fatiguing the eye that different results were obtained. After fatigue with the monochromatic yellow light the spectrum appeared to be greatly modified in appearance : yellow appeared neutral grey, red and orange appeared crimson, yellow-green and green appeared bluegreen and blue and violet were much darkened. On the other hand, exposure of the eye to the red and green mixture darkened the entire spectrum and produced slight selective effects on the colours of its different parts, but not of the same degree as those produced by the monochromatic yellow light. On the trichromatic theory it is difficult to explain why these two lights which resemble one another so closely should produce different fatigue effects. According to the polychromatic theory, on the contrary, the monochromatic yellow light stimulates the yellow receptors strongly and the orange, red, green and bluegreen receptors feebly. The dichromatic yellow light stimulates the red, orange, green and bluegreen receptors strongly and the yellow receptors feebly ; hence different results are achieved on subsequently examining a spectrum.

It remains briefly to refer to the curious inhibiting effects which exposure of the eye to monochromatic yellow light has on the subsequent perception of blue and violet, and that which exposure of the eye to blue or violet has on the subsequent perception of yellow. This is paralleled by similar effects when both are situated side by side in the same visual field, attention to which has been directed previously by the author (1947). It would appear possible that both simultaneous and subsequent presentation operate in a similar manner just as simultaneous and successive contrast appear to do. It is hoped to deal elsewhere with this subject in greater detail.

SECTION 10

SATURATION DISCRIMINATION

The apparent saturation of the spectral colours is disturbed by actual or potential neutral points caused by the response curves of the receptors occupying complementary or nearly complementary positions in the spectrum. Thus for the protanope who possesses two types of receptor only, which are complementary to one another, there is an actual neutral point at about $0 \cdot 49\mu$.

To take a second example ; to the fovea of the normal subject when observing test

objects at small visual angles, there is dichromatic vision probably due to the activity of the R - BG - R unit in a pure state. Now the red and the bluegreen receptors are complementary to one another and in consequence there are two actual neutral points, at 0·578μ and 0·41μ (Willmer and Wright, 1945).

To take a third example ; it was found by Chapanis (1944) that to the protanomalous subject the spectrum at 0·49μ is nearly neutral and there is a second not well marked potential neutral point at 0·56μ. In these subjects, who have only three types of receptor in a functional state, no one pair is complementary to any other pair but the red and the green receptors produce the potential neutral point at 0·56μ and the two acting together produce with the blue receptors the nearly neutral point at 0·49μ. Now the tricolour unit of the normal sighted subject closely resembles, if it is not identical with, the visual unit of the protanomalous subject. If this be correct, the tricolour unit is responsible for one nearly neutral point at 0·49μ and for one point of poor saturation at 0·56μ. Similarly the Y - B unit of the normal sighted is found to have an actual neutral point at 0·526μ and, as we have seen, the R - BG - R unit possesses two actual neutral points at 0·578μ and at 0·41μ.

Taking these neutral points in turn there are two in the yellow, one caused by the R - BG - R unit and one by the tricolour unit. These correspond in wavelength to the crests of the yellow receptors of the Y - B unit. Now this is only a subsidiary unit so that the yellow receptors modify but slightly the potential neutral point produced by the other two units. The consequence is that the yellow region of the spectrum is a point of low saturation. The next neutral point in the spectrum is at 0·526μ, due to the Y - B unit, but this is close to the crest of the important green receptors of the tricolour unit, the consequence being that this potential neutral point does not disclose its presence in normal colour vision. In a similar manner the neutral point at 0·49μ due to the tricolour unit coincides almost exactly with the crests of the bluegreen receptors of the R - BG - R unit and is thus covered up. Lastly the neutral point at 0·41μ belonging to the R - BG - R unit is not far removed from the crests of the indigo receptors of the tricolour unit and is thus hidden by them. The conclusion is that of all these potential neutral points the only one of consequence in normal vision is the one which occurs in the yellow part of the spectrum. This conclusion, which has been arrived at on the basis of the polychromatic theory, is in good agreement with the experimental data, because, as is well known, the point of lowest saturation in the spectrum is in the yellow. The three-colour theory can offer no explanation of the variation of saturation with wavelength exhibited by the protanomalous and the normal sighted.

Section 11

The Antichromatic Responses, the Fixation Points and the Subjective Colours

Having reviewed in the previous sections some of the aspects of human colour vision for which the three-colour theory is unable to provide a satisfactory account, but which can be explained on the polychromatic theory, it is now necessary to re-examine the experiments referred to in the introduction, which being of a subjective nature might not alone be considered to carry much weight, but materially add to the evidence given in sections 2 to 10 of this address. The experiments referred to are those on the antichromatic responses, the separate fixation points of the different colours and lastly the subjective estimates of hue when by means of a microstimulator and in the presence of conditioning stimuli a tenuous beam of white light is caused to explore the retina.

Ever since the days of Thomas Young it has been agreed that the lens system of the eye suffers from chromatic aberration. The most recent measurements of the aberration at different wavelengths were made by Ivanoff (1947) and by the author (1947). Agreement between them is extremely good, so good in fact that further estimates on healthy emmotropic or nearly emmotropic subjects would appear to be unnecessary.

Now an examination by means of a microscope or high power eyepiece of the images produced by uncolour-corrected lenses shows that colour fringes are present at the borders separating the light and the dark parts of the pattern present in the visual field. These fringes at the optimum focusing point are yellow and blue. But it is a matter of everyday experience, that the presence of these coloured fringes is seldom observed in normal vision. Experiments of a simple and reliable nature using blue and yellow test objects, both those produced by the use of dyes and colour filters and by means of a suitable spectrometer, show that there is present in connection with vision a mechanism of some kind which can not only eliminate the coloured fringes produced by the chromatic aberration of the eye, but the colours of yellow and blue test objects as well. Experiment shows that many factors are concerned with this elimination, the intensity of illumination, the relative intensities of the spectral

components present in the fringes, etc. Of special importance are the proximity of yellow and blue because this is found to facilitate greatly the loss of hue by both colours. A number of different hypotheses have been advanced by the author in order to account for these facts, but one alone stands up to detailed examination, one moreover which is based on the polychromatic theory, namely that the proximity of the blue and the yellow fringes, which is always found to occur when they are produced by chromatic aberration, aids the inactivity in the first place of the Y - B unit and in the second place of the tricolour unit, so that the only visual unit left in action is the R - BG - R unit. There is evidence which supports the view that these changes are brought about by a nervous mechanism which has been called by the author the antichromatic responses.

Some theories require, in a manner at present unknown, all colour receptors to respond efficiently to all parts of the spectrum. As an example of these the theory advanced by Wright (1942) may be quoted. He writes : 'the triple sub-division may very possibly occur within the cones on a submicroscopic scale which cannot be revealed by our present techniques.' Apart from these theories which postulate that all cones respond to all colours, the remaining theories suppose the receptors to be divided into a certain number of different types. In the case of the three-colour theory there are obviously three types, in the case of the polychromatic theory several types, and so on. Now these theories automatically require there to be different fixation points for different colours, since it is obviously impossible to suppose that a given receptor fixes all colours, both those which come within the range of its response curve, and those which do not. Thus in the case of the three-colour theory there must be three different fixation points, one for red rays, one for green rays and one for blue rays. A four-colour theory will correspondingly require four fixation points and so on. Whatever the number may be, several different fixation points would be expected and such an expectation is derived from first principles and is not directly dependent on the cluster hypothesis, with which it is in complete accord, since the most likely situation for a fixation point, for a particular colour, is near the centre of a cluster of receptors which respond to that colour.

It will be recollected that two different methods were employed by the author (1947) when determining the positions of the fixation points in the foveal area : (*a*) the kinaesthetic method, which depended on the subjective appreciation of eye movements, and (*b*) the local scotoma or blind spot method. These methods gave confirmatory results. That local scotomata are present near the foveal centre was first discovered by Franklin (1894) and was supported by Wilbrand (1896). That the position of the fixation point is a function of the wavelength has been suggested by some experiments performed by Thomson (1946). This conclusion is substantiated by the observations made by the author. It is reasonable therefore to accept the hypothesis (*a*) that there are different fixation points for the different colours, (*b*) that their positions can be determined by suitable methods, (*c*) that their positions are a function of the wavelength. The author decided that there were seven different fixation points at a time when he was unaware of the large mass of evidence in favour of the polychromatic theory. These pieces of evidence therefore provide strong support for one another.

Probably the first experimenter to apply the principle of microstimulation to the human retina was Holmgren (1880), who caused the image of a very small point of light to pass slowly over the surface of the fovea. When the source of light was yeliow Holmgren found that it was seen as red in some positions and as green in others. It was thought at the time that this gave strong support to the tricolour theory but we now know, in view of the antichromatic responses, that this is not the case. In the same year Fick (1888) found if a source of coloured light be sufficiently reduced in visual angle that it becomes colourless. He also found if two or more such sources of the same colour be reduced in visual angle until seen separately they appear colourless, that when seen together their colours are restored. These observations of Holmgren and Fick have been confirmed and extended by the author using the microstimulator in combination with a spectrometer for obtaining monochromatic light. On the basis of the three-colour theory it would be expected that when the image of a small source of white light is caused to move slowly over the surface of the fovea that it would be seen as red in some positions, as green in other positions and as blue in yet other positions. But in addition to these colours the author has also observed orange and bluegreen. When suitable conditioning stimuli are present at the same time, as used by Fick, yellow and violet are also to be seen making seven colours in all. This is one more piece of evidence which supports the polychromatic theory.

Section 12

Some Other Receptor Arrangements

When alternative hypotheses to the polychromatic theory were examined by the author particular attention was paid (*a*) to

modifications of the three-colour theory ; (*b*) to three-channel hypotheses.

One modification of the three-colour theory has already been referrred to in this address, namely, linking between the red and the green receptors at the fovea at high light intensities and at the periphery of the retina, and linking between the green and the blue receptors at the fovea at low light intensities and at small visual angles. Of all the modifications of the classical three-colour theory this seemed to the author to be the most promising. It fails, however, mainly for three reasons : (*a*) it gives no explanation of the changes in shape of the luminosity curve ; (*b*) it gives no adequate account of the differences of colour vision between the true trichromats, that is of subjects with normal sight, on the one hand, and between the protanomalous and the deuteranomalous on the other ; (*c*) it does not comprise the necessary number of different types of receptor to comply with the requirements of the phases of vision referred to in sections 3, 4, 5, 8, 9 and 11 of this communication ; in consequence there is no alternative but to abandon this attractive hypothesis.

Of the three-channel hypotheses one of the best known is that proposed by Granit himself soon after his discovery in the mammalian retina of modulator response curves. His suggestion was that the nerve pathways from the orange and the yellow modulators might converge on to a single channel, that the three green modulators might do the same, and similarly for the two blue ones. Thus there would be polychromatism in the retina but trichromatism in some part or parts of the nervous channels between the receptors and the brain, and possibly in the brain itself. Le Gros Clark (1941), as the result of a histological survey of the external geniculate body of the monkey, has proposed that this structure forms a part of this triple channel. Now there can be little doubt that this hypothesis is in certain respects an improvement on the preceding one ; thus the polychromatism of the retina offers an explanation of the retinal direction effects which depend on local conditions. It also accounts for the many different fixation points. Important facts which it cannot deal with are spectral mixture, hue discrimination and the essential differences between the normal-sighted subject and the anomalous trichromat, all of whom must use the same three channels if this hypothesis is correct. But apart from these general criticisms there are some special ones, because Le Gros Clark has claimed that the periphery of the retina is dichromatic, with yellow and blue as primary colours. But this is only true at moderate intensities of illumination and ceases to be so if the light intensity be increased. He has also claimed that the fovea is dichromatic, with red and bluegreen as primary colours. But in this case also the dichromasy is conditioned by light intensity and disappears if this be increased. Lastly, the external geniculate body, if Le Gros Clark's description be correct, contains no provision for a channel connecting the rod receptors with the brain. If this does not pass through the external geniculate body, what course does it pursue ? These are but a few of the difficulties which beset this three-channel theory.

Of four-colour theories the only one which need claim attention here is that originally proposed by Hering (1874), because it is representative of the others. The four most likely receptor types have response curves with crests in the red, the yellow, the bluegreen and the blue, but the red receptor also has a subsidiary response in the violet part of the spectrum ; in consequence the four types of receptors comprise five response curves. Since the red and the bluegreen receptors are complementary, and since the former also acts in the violet, they form a unit which may be identified as the R - BG - R unit of the polychromatic theory. In the same way the yellow and blue receptors of Hering's theory, since they are complementary, may be identified as the Y - B unit of the polychromatic theory. Thus Hering's theory in a modern form may be regarded as similar to the polychromatic theory, from which the tricolour unit has been omitted. What then would be the disadvantages of doing this? For normal foveal vision both units would be in operation. On reducing light intensity or visual angle the Y - B unit would drop out leaving the R - BG - R unit alone in action. At high light intensities the Y - B unit would be the only effective one. The same unit would operate when there is dichromasy of the retinal periphery. Since these units comprise complementary pairs of receptors the constancy of white under all these conditions is satisfactorily accounted for. The varieties of colour blindness are not so readily explained. Protanopia might be due to the Y - B unit, and deuteranopia to linkage of the yellow and the red receptors to form a single receptor mechanism together with the corresponding linkage of the bluegreen and the blue receptors to form the second receptor mechanism. Protanomaly might be caused by linkage of the red and the yellow receptors, the green ones and the blue ones acting separately. Deuteranomaly might be caused by linkage of the green and the blue, the red and the yellow receptors acting separately and so on. Where the four-colour theory fails most obviously is when it attempts to fit in with hue discrimination data.

An examination of other theories leads to the final conclusion that only the polychromatic theory is in agreement with all the known facts, and that this must extend not only along the nervous channels which connect the receptors to the brain but must also apply to the brain itself.

Summary

Until a few years ago it was possible to account for nearly all the aspects of human colour perception on the basis of the three-colour theory, but such is no longer the case. This is largely due to improvements in the older methods of investigation and to the invention of new ones. Among the latter may be mentioned the micro-electrode technique of Granit and the retinal direction effect of Stiles and Crawford. Modern requirements are met by a polychromatic theory, comprising seven types of receptor, but there is no necessity for these to have such narrow spectral response curves as those exhibited by Granit's modulators. Modifications of the three-colour and four-colour theories have been examined to see to what extent they can be made to fit in with experimental results. Particular notice has been taken of the possibility that there is polychromatism of the retinal receptors but trichromatism of the nerve paths which connect these to the brain, or even to the brain itself.

The conclusion arrived at is that there must be polychromatism throughout the entire visual mechanism for colour perception if a complete account is to be given of all the known facts.

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SECTION J.—PSYCHOLOGY

PRESENT-DAY TRENDS IN BRITISH PSYCHOLOGY

ADDRESS BY
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MORE than sixty years have now passed since the *Encyclopædia Britannica* in 1886 first published Ward's famous article on 'Psychology,' whose attack on associationism, which was then the reigning psychological theory, was hailed by William James as 'marking the transition of British psychology from one epoch to another.' More than forty years have passed since the meeting of the British Association in York in 1906, when the President, Sir Edwin Ray Lankester, devoted a section of his address to 'Psychology,' because, as he said, 'the emergence of psychology as a definite line of experimental research seems to me one of the most important features in the progress of science in the past quarter of a century.' Nearly thirty years have passed since psychology, at the meeting of the British Association in Edinburgh in 1921, was given full sectional status, and Lloyd Morgan, our first President, using his concept of 'emergent evolution,' attempted to 'link up psychology with other branches of science under one consistent scheme of natural development.' It may therefore now be appropriate to review the progress of psychology in Great Britain during the past sixty years, to note particularly the striking changes that have occurred in its scope, methods and applications, and to discuss its present-day trends.

I.

Apart from its attack on associationism, Ward's article had little effect on the nature or scope of psychology. Its very appearance did indeed show that, in the view of the editors of a great Encyclopædia, psychology, which had previously been treated merely as a branch of metaphysics, should be accorded the status of a subject in its own right. Also, the article itself emphasised that psychology is not a branch of analytic or speculative philosophy, but a positive science concerned with the systematic investigation of matters of fact. But Ward did not markedly change or extend the subject-matter of psychology, and it may fairly be said that in British universities sixty years ago, even in those that Ward's article influenced, psychology generally had the following five characteristics: it treated man as though he were a disembodied spirit; it was almost exclusively concerned with the processes involved in the acquisition of knowledge; it neglected animals, and, among human beings, paid little attention to children, primitive people, or the abnormal; it regarded man mainly as an isolated individual; and it had nothing to say about psychometry. As present-day British psychology has none of these five characteristics, it is instructive to examine each in turn, and to consider the trend that its disappearance indicates.

In the first place, in 1886 the view that man is an embodied mind, or an animate organism, was not regarded with favour by most of the philosophers who then were responsible for most of the teaching of psychology in British universities. Everyone admitted, of course, that what goes on in our body is not wholly irrelevant to our thought and behaviour, but it was considered wise, or perhaps merely prudent, to avoid giving a detailed account of the inter-connexion between our mental and physiological processes. This attitude was due partly to the belief that, if what goes on in our mind is affected by what goes on in our body, the importance and dignity of the mind are in some way diminished; and partly to a recognition of the fact that, although we may be able to *explain the occurrence* of mental experiences by reference to physiological processes, we cannot *describe the nature* of mental experiences by reference to such processes. It was also due to fear of acquiring a reputation for materialism, and of suffering the consequences that this reputation would entail. After all, the excitement caused by the British Association addresses of Tyndall and Huxley on the relation of body and mind was still much in evidence in 1886. The atmosphere, which, according to Sir Oliver Lodge, had 'begun to smell of

brimstone' at the famous Belfast meeting in 1874, was still sulphurous and intimidating, and University pulpits were still 'fulminating anathemas at the men of science.' Bain, it is true, had recognised as early as 1857 that a psychologist must know some physiology, and had devoted part of *The Senses and the Intellect* to a detailed account of the structure and functions of the sense organs, the nervous system and the muscles. But this did not help matters. Bain was associated with Tyndall, Huxley, Clifford and Lewes, and shared their dangerous thoughts; and he himself had had painful experience of *odium theologicum* before his own University in Aberdeen appointed him its Professor of Logic. His example was not one that it was expedient for a young philosopher, eager for academic advancement, to follow. Consequently, it is not surprising that even Ward makes little more than perfunctory reference to physiological psychology—'there is' he says, 'nothing to prevent the psychologist taking counsel with the physiologist'—and that he tends to damn it with the faintest of praise.

In contrast to this grudging acknowledgment of the value of physiological psychology, every modern textbook of psychology, and every present-day University course in psychology, is based on the view that knowledge of certain physiological facts, particularly facts about the sense organs, the nervous system and the endocrine organs, is indispensable to the study of thought and behaviour; and whole treatises, like Morgan's *Physiological Psychology* are now devoted to the subject. This change is the result o various influences. Among the earliest and most powerful were the persuasive advocacy and example of James and Sully. James always assumed and proclaimed, as a working hypothesis, that mental action is 'uniformly and absolutely a function of brain-action, varying as the latter varies, and being to the brain-action as effect to cause.' Similarly, Sully, when he expanded his *Outlines* of 1884 into *The Human Mind* of 1891, added several chapters on physiological psychology, saying that this addition 'may be taken to mean that I am far from the standpoint of that psychological asceticism, which, disowning the poor body altogether, seeks at this time of day to elaborate a theory of mind-action *ab intra* and without any reference to the system of organic forces which is conditioning this action at every point.' Other influences that have helped to establish physiological psychology have been the gradual acceptance of the evolutionary theory, with its tendency to assimilate the study of man to the study of the other animals, and the researches of neurologists, like Lashley and Sherrington, who set out to explore the functions of the nervous system and the connexion between mental and physiological processes. But no doubt the greatest influence has been that of the Behaviourists, especially Watson, whose *Behaviourism* was described by an impressionable New York paper as 'perhaps the most important book ever written.' Watson's powerful propaganda, which made use of reiterated assertion, ridicule, the appeal of the bandwagon and many other effective devices, was designed to establish two views: that scientific psychology must discard altogether the study of mental experiences and confine itself to the study of behaviour; and that all behaviour is merely a matter of simple and conditioned reflexes. And, even though it did not achieve this mistaken aim, Behaviourism did at least establish that psychology must be concerned with behaviour as well as mental experiences, and must take into account the physiological processes that underlie both.

Secondly, British psychology in 1886 was preoccupied with cognition. Bain is again to be excluded from this broad generalisation. He had written *The Emotions and the Will* as well as *The Senses and the Intellect*, and had devoted a great deal of attention to motivation. But here, as elsewhere, his example was not widely followed by those who were teaching psychology in the last fifteen years of the nineteenth century. Ward's article, although it stressed the general importance of conation in all mental activity, had little to say about our feelings and desires: it was almost wholly concerned with sensation, perception, imagery, memory, reasoning, and other intellectual processes. Similarly, Stout's *Manual*, which appeared in 1899, contained an elaborate account of sensation, perception and what he called 'ideational and conceptual process;' but it devoted less than three per cent. of its pages to emotion, which was treated in the section headed 'Perception.' It is this preoccupation with cognition—coupled, of course, with their exhaustive discussion of problems that lie on the border between psychology and philosophy—that chiefly makes Ward and Stout, for all their merits, seem now very old-fashioned and rather arid.

Present-day psychology is at least as much concerned with the springs of thought and action, and the nature of personality, as with the processes involved in the acquisition of knowledge. This change was brought about chiefly by James, McDougall and Freud. James's influence was effected mainly through his *Principles of Psychology*, whose brilliant style and rich, concrete illustrations (to say nothing of its moral conviction) made it a popular classic. This book showed on every page James's real and lively interest in human beings, their hopes and strivings, their desires

and fears, as well as the operations of their intellect; and its whole approach to the study of thought and behaviour, as well as its famous chapters on such topics as instinct and habit, modified the syllabus of many a course in psychology in Britain as well as America. McDougall also exercised an immense influence in breaking down the intellectualism of British psychology as it was left by Ward and Stout. His *Introduction to Social Psychology*, which was first published in 1908 and is now in its twenty-eighth edition, deals with instincts, emotions, sentiments and the formation of character. It has been studied by generations of students, and has provided the text for innumerable discussions of motivation; and, although it raises many difficulties and has given much offence to all Behaviourists and many sociologists, Flugel was not exaggerating when he described it, in *A Hundred Years of Psychology*, as 'without a rival in completeness and thoroughness, and in penetration second only to the work of Freud.' But, undoubtedly, the most important influence in directing the attention of psychologists to psychodynamics was Freud. It was he, more than any other, who brought under investigation 'the motives underlying our loves and hates, our interests, our longings, our work and our play, our difficulties, failures, maladjustments and general unreasonableness.' For a long time, owing to their aversion from his insistence on the importance of sex, British universities excluded Freud and psychoanalysis from their courses —or included them only in order that they might be castigated and quickly expelled. Even twenty years ago *The Psychopathology of Everyday Life*, which is now one of the Penguin books, was kept under lock and key in some University libraries, and could be read only by special permission. But Freud's influence was nevertheless breaking in, and those aspects of the mind to which he devoted himself, particularly the nature and rôle of the unconscious, the course of emotional development, and the 'mechanisms' whereby the mind seeks to resolve or evade its internal conflicts, now loom large in psychology.

Thirdly, British psychology sixty years ago was mainly concerned with ascertaining the nature and inter-relations of what was called 'developed consciousness.' Ward, in the introductory section of his article, recognised that the psychologist is entitled to take account of 'the materials furnished by his observation of other men, of infants, of the lower animals, or of the insane'; and, like Stout, he had once hoped to provide a genetic treatment of mental processes 'from the lowest planes to the highest.' In actual practice, however, both these psychologists concerned themselves mainly with human beings, and with human beings who were adult, civilised and normal. They referred only incidentally to animal psychology, child psychology, anthropological psychology, or abnormal psychology, each of which is now a conspicuous feature of the psychological landscape.

The neglect of animal psychology by academic teachers in the eighties was not due to its non-existence. The new, evolutionary outlook in biology, and the inspiration of Darwin and Spencer, had already directed attention to the mental experiences of animals. Before Ward's article appeared, Spalding had conducted experiments into the part played by instinct, as distinct from experience, in animal actions; Schneider had advanced his arguments for recapitulation; Weismann had propounded his theory of the continuity of the germ plasm; Fabre and Lubbock had embarked on their studies of insects, and Romanes had published his anthropomorphic anecdotes of animal exploits. But this work lay outside the scope of British psychology as it was set forth in British textbooks in the eighties.

The study of the mental processes and behaviour of animals did not achieve an established place in psychology until the nineties, when in England Lloyd Morgan, with his rigorous 'canon of parsimony,' began to observe, under pre-arranged conditions, the behaviour of animals in their normal environment, and in America Thorndike, with his puzzle-boxes, began his series of laboratory investigations into the process of learning in cats, dogs and chickens. Since then, discussions about animal intelligence and behaviour have become prominent in British psychology, not merely owing to the contributions of Lloyd Morgan and Thorndike, but also as a result of the work on conditioned reflexes of Pavlov and Bechterev, the controversies about the rôle of instinct and insight in animal learning raised by the Behaviourists and the *Gestalt* psychologists, and McDougall's prolonged but fruitless attempt to rehabilitate the Lamarckian doctrine. But, although these discussions are to the fore in present-day British psychology, it would be disingenuous not to confess that hardly any of the more recent researches that underlie them have been carried out in Great Britain.

Child psychology, too, has arrived during the past sixty years. Sully founded the British Association for Child Study in 1893, and published *Studies of Childhood* in 1895; and his work, as well as the American work of Stanley Hall and Mark Baldwin, which became widely known in British psychological circles, set going the systematic investigation of normal, handicapped and maladjusted

children, which is now one of the most important branches of British psychology. In this connexion, as in others, Burt's influence has been important. His *Young Delinquent* gave many fascinating case-histories of children with whom his work as Psychologist to the London County Council had brought him into professional contact, and it made clear the general conclusions regarding the causes and treatment of delinquency that emerged from his observations. So far as Great Britain was concerned, this book was the *fons et origo* of what is now known as ' child guidance '—the expert diagnosis and treatment of children who exhibit some defect or disorder of thought or behaviour, which unaided common-sense cannot explain and the normal methods of correction cannot remove. Moreover, three other books by Burt—*Mental and Scholastic Tests*, *The Backward Child*, and *The Subnormal Mind*—have also greatly assisted in raising child psychology to a position of prominence.

But other influences, too, have been at work. In particular, a great impetus was given to child psychology by Freud and Adler, who, however much they differed in other respects, both emphasised the importance of infancy in emotional growth, and taught that the conflicts that cause breakdown in adult life are those that revive the unresolved conflicts of childhood. Also, the Behaviourist view, that children can be moulded in any of an indefinite number of ways by merely establishing in them the appropriate conditioned reflexes, has naturally met with an enthusiastic reception among those who believe, or at least hope, that all human defects and failings are mainly the result of a faulty environment and can be prevented by proper training and care. And even the majority of psychologists, who regard human beings as rather less malleable and perfectible than Watson and other environmentalists like to suppose, have been led by Behaviourism, as well as by psychoanalysis and its derivatives, to take an interest in the scientific study of child development—an interest which was almost unknown in the eighties.

Like animal psychology, anthropological psychology arose from the general interest in the development of human life that the theory of evolution and the influence of the great Victorian scientists had aroused. As early as 1871 Tylor's *Primitive Culture*, with its doctrine of animism, had kindled the flame of what is now known as ' cultural ' or ' social ' anthropology ; and in 1876, in the very first number of *Mind*, Spencer had written on ' The Comparative Psychology of Man.' But it was not until the end of the century, when Frazer's *Golden Bough* had begun to produce its momentous effects, that psychologists began clearly to see that the study of savages is important, not only for its own sake, but also for the way in which it illuminates all human behaviour. By that time, social anthropology had become practically useful as well as theoretically interesting, because problems of colonial administration in Africa and elsewhere had demonstrated the need for a fuller understanding of primitive people and their social organisation. Moreover, some of the social anthropologists began to be much influenced by hypotheses and concepts that psychologists had developed. Consequently, from the beginning of the present century, anthropological psychology began to attract increasing attention among psychologists, and there are now few British universities in which students can study psychology and be left unacquainted with Frazer's account of magic and religion, Marett's insistence on the importance of ' mana,' Freud's *Totem and Taboo*, or the findings that have issued from the field-researches of such anthropologists as Malinowski, Ruth Benedict and Margaret Mead.

Abnormal psychology, also, has made great strides since Ward cautiously admitted that psychologists might legitimately consider facts about the insane, and James scandalised some of his contemporaries by including in his *Principles* a chapter on ' exceptional mental states.' Sixty years ago British psychology did not altogether neglect previous work connected with hypnotic phenomena, and with the distinction between insanity, mental deficiency and criminality ; but its concern with the ' normal ' human being was almost, if not quite, exclusive. It was the French psychologists, Charcot, Ribot, Janet and Binet, who originated the modern development of psychopathology. It was their work on ' diseases ' of memory, will and personality, and their investigations into hysteria, dissociation and the therapeutic value of disinterring buried memories, that first made a place for psychiatry in scientific medicine, and first showed that abnormal psychological data can throw a flood of light on normal thought and behaviour. Moreover, it was Charcot, as well as Breuer, who first stimulated Freud's interest in the systematic study of the unconscious, and of its intricate influence, not only on neurotic and psychotic conditions, but also on everyone's everyday life.

Freud and his associates have, of course, been the chief influences in the development of psychiatry during the present century, and their influence has not been confined to those who profess and call themselves psychoanalysts. But the contributions of Adler and Jung have also been important. Freud, Adler

and Jung, although they differ about the nature of the unconscious and about other psychological matters, all agree that irrational tendencies of which we are normally unaware (which are unconscious) profoundly affect our thought and behaviour ; they agree that neurosis springs from the conflict of these tendencies with one another, or with our conscious desires and the requirements of reality ; and they agree that, in the effective treatment of neurosis, the patient must be helped to become aware of these conflicts and to solve them by rational means. The common ground that thus exists between these psychologists has greatly affected psychological medicine. In Britain, in 1912, it formed the basis of Hart's remarkable little book on *The Psychology of Insanity*, whose moderation, lucidity and persuasiveness commended the new dynamic picture of the individual to countless readers. And in the two World Wars, which involved numerous mental as well as physical casualties, it supplied the technique, which, along with such recent physical methods of psychiatry as insulin-shock and electrical convulsant therapy, enabled many mental disorders to be effectively treated.

Fourthly, psychology in 1886 was generally regarded as the study of man as an isolated individual, and there was none of the present-day emphasis on the social aspects of thought and behaviour. Although Comte's positivism, with its three stages of social development, had been introduced by John Stuart Mill into advanced intellectual circles, and although Spencer's *Principles of Sociology* also had awakened an interest in social evolution, British psychologists in the eighties were almost exclusively concerned with the individual. Thus Ward's few and meagre references to what he called ' intersubjective intercourse ' were in no way atypical ; and Stout, when he was writing his *Analytic Psychology*, which was published in 1896, felt no qualms in confining his treatment of the social factor to its influence on the growth of the individual's theoretical interests.

It was James, with his interest in every aspect of human experience, who, in his *Principles*, gave the first impetus to social psychology—an impetus that was soon reinforced by Tarde's *Laws of Imitation* and Le Bon's classic work on *The Crowd*. But it has been during the present century that the great growth of social psychology has taken place. This has derived from various sources : partly from McDougall, whose work on *The Group Mind*, as well as his *Introduction to Social Psychology*, provoked a widespread response ; partly from the social anthropologists, with their comparative studies of the social behaviour of savages ; partly from Freud, Adler and Jung, who have all emphasised the importance of family and other social relationships ; partly from the *Gestalt* psychologists, who lay stress on the influence of the whole on its parts, not only in the organisation of the sensory field, but also in social organisation ; and partly from the steady streams of detailed, first-hand studies of concrete social situations that have poured from the many centres of sociological research in America. The development of social psychology has also been powerfully aided by the Zeitgeist—by that transfer of attention from the individual to the group, that emphasis on the Social Gospel, which colours so much contemporary thought, and represents a striking change of wind in political and social philosophy.

In the result, social psychology is now one of the most notable branches of the British psychological tree. Psychologists, like sociologists, are investigating the influence of a great variety of social factors on a great variety of mental processes and patterns of behaviour. They are concerning themselves with such social phenomena as class stratification, the cinema, propaganda, the social aspects of religious behaviour, and the forces that make for cohesion or conflict in occupational, regional, national, ethnic and other groups. They are also studying the statistical techniques most appropriate to subtle problems of social research, so that their concrete observation can be controlled with technical rigour. And, finally, they are attempting to formulate the general hypotheses and systematic intellectual framework that are necessary if social surveys and similar factual studies are not merely to assist in the solution of practical problems, but also to contribute to psychological and sociological theory.

Fifthly, the last sixty years have witnessed the development of mental tests, which now include tests of various temperamental traits as well as tests of intelligence, special aptitudes and attainments. In a sense, Galton was the originator of mental tests—as he was of so many other things—since it was he who first sought to investigate statistically the inter-relations of mental traits. But it was J. M. Cattell who invented the name ' mental test,' when he used it in 1896 to describe psychological tests that he had applied to Columbia students ; and mental tests, as we now know them, first began to be constructed in the early years of the present century.

Although tests of temperament are comparatively recent and must be regarded as still undergoing their trials, psychological tests of intelligence, aptitude and attainment have now been in use for some fifty years. These tests have both a practical and a theoretical value, since they can be profitably employed,

not only in the assessment of mental traits for practical purposes, but also in investigations into the nature and correlation of mental traits. Their practical uses are many and various. Among the chief of these are : the diagnosis of mental deficiency ; the grading of pupils according to their ability and aptitude ; and vocational guidance and selection. Mental tests, particularly tests of intelligence, are now widely employed in education as part (but, of course, only as part) of the procedure for promoting children from primary to secondary schools. And in the Second World War they were applied on a large scale in the British and American Forces as part of the selection procedure whereby recruits were assessed, and allocated to appropriate duties.

Their use in purely scientific investigations has revealed many interesting facts. It has shown, for example, that all human abilities are positively correlated ; that this correlation is probably due to their each depending partly on a general factor that runs through them all ; that this factor corresponds to the 'intelligence' of common speech ; that it is largely hereditary, ceases to grow after the age of 16 or 17, and rusts with disuse ; that there is no significant difference in intelligence between the sexes ; that there is a definite relation between subnormal intelligence and delinquency ; and that, in addition to the general factor, there are also group factors, such as numerical ability, verbal facility and mechanical aptitude, each of which affects a group, but not all, of our activities. The scientific use of mental tests has also led to considerable developments in statistical theory, especially in relation to social and biological data ; and here, as well as in the construction of actual tests, Burt, Spearman and Thomson have constituted a great triumvirate in British psychology.

II

Since Ward wrote his article, British psychology has developed in method as well as in scope. In 1866, it was almost wholly based on introspection ; it was non-experimental ; and it was much given to anecdote. Now, observation of behaviour and exploration of the unconscious are at least as important as introspection ; experimental psychology has established itself ; and the anecdotal method, though unfortunately still sometimes to be encountered, has almost disappeared.

Observation of behaviour, although its value was acknowledged, was very little practised by psychologists in the nineteenth century. It came into its own mainly as a result of the Behaviourists' insistence that *only* behaviour should be, or can be, observed. They propagated the view that introspection consists either in looking for something that is not there (for some Behaviourists denied the existence of mental experiences), or in inspecting data, which, because they are private, non-recurrent, and insusceptible of the same sort of measurement as physical objects, cannot constitute the basis of any science. This view corrected one kind of inadequacy by introducing another, and is no longer widely held in psychology. Most present-day psychologists agree with Myers, who said : 'To neglect introspection in psychological experiment is usually to court certain disaster. If we are in total ignorance of what has been going on in the mind of the subject during the experiment, it is rarely possible to argue from the objective data—from the measurements which it yields.' Nevertheless, the Behaviourist doctrine fulfilled a useful function. The persistence and skill with which it was pressed, and the valuable experimental work in physiological psychology, animal psychology and educational psychology that was carried out under its inspiration, focused attention on the importance of developmental and other behaviour-studies, and was mainly responsible for the fact that, whereas psychology was usually defined sixty years ago as the science of mental experience, present-day textbooks are careful to add 'and behaviour.'

The limitations of introspection were also made plain by the psychopathologists, who found that some of our most important mental processes are unconscious and non-introspectible. But this group of psychologists were less opposed to introspection than to the preoccupation with conscious or 'surface' experiences which it presupposed : and they were less concerned with the study of overt behaviour than with developing clinical methods, such as free-association and dream analysis, whereby the unconscious 'depths' of the mind could be explored.

In the last twenty years of last century, experimental psychology, which was so prominent in Germany and America, was almost unknown in Great Britain. Sir Ray Lankester's remarks in 1906 about 'the emergence of psychology as a definite line of experimental research' had little reference to British psychology. Certainly Galton had carried out many psychological experiments ; Sully, in 1876, had called the attention of the readers of the first number of *Mind* to the experimental work that was going on in Germany under Fechner, Helmholtz and Wundt ; and in 1886, the year of Ward's article, *Mind* published the plea for a Society of Experimental Psychology which Jacobs had made at that year's meeting of the British Association in Aberdeen. But, so far as Great Britain was concerned, experimental psychology did not

get on to its feet until the beginning of the twentieth century, when McDougall, Myers, Spearman and Drever embarked on laboratory research and introduced laboratory work into their courses. Since then it has grown apace, and now no University Department of Psychology lacks its chronoscopes, tachistoscopes, colour-wheels, kymographs and the like.

Some of the earlier laboratory psychology, it must be confessed, seems to have been based on the assumption that the use of elaborate apparatus is an end-in-itself. Many besides James have found such laboratory work ' mere patient drudgery, quiddling and irksome, trivial and disappointing—an idol of the cave, whose only function is to keep the laboratory instruments going.' But these teething troubles were only to be expected in a new science, especially one whose uncertain scientific credentials and non-material subject-matter made many psychologists feel that it was very important to seem, as well as to be, ' scientific.' With the passing of the years (to say nothing of the growing of the teeth) these troubles have subsided, and laboratory psychology has become both more interesting and more important than it was when Titchener and the Wundtian approach to psychology were in the ascendant. It has made possible, for example, many of the advances in our understanding of physiological psychology, of perception, and of the factors involved in animal and human learning.

Moreover, experimental psychology has come to comprise much more than laboratory work. It is now being increasingly recognised that many valuable psychological experiments can be, and must be, conducted outside the laboratory. For example, investigation of such topics as propaganda, rumour, the causes and effects of different ways of treating infants in different societies, or the influence on an individual of the personal relations in his group, demand field experiments, in which people are studied in real-life situations and we do not pull up the plant to see how it grows. As a result a good deal of modern experimental psychology, especially in America, and especially in relation to the social aspects of thought and behaviour, is not carried on in a laboratory. Thus, social psychologists, as has already been said, are making first-hand studies of actual social phenomena ; educational psychologists are conducting experiments among children in schools ; in mills, mines and factories, industrial psychologists are investigating incentives, selection, methods and conditions of work, and industrial accidents ; and medical psychologists are extending their clinical study of mental illness into the wider field of mental health.

It need not be stressed that in all experimental work in psychology, as in the other biological sciences, expert statistical control is indispensable. In every investigation the principles and techniques of statistics must be employed, not only in the interpretation of the data that are collected, but also in the preliminary decisions regarding what data will be crucial to the question or hypothesis being investigated. The statistical side of psychology has received great attention in Great Britain, and in this field several younger psychologists, as well as the three older psychologists mentioned in connexion with mental testing, have achieved international fame.

The introduction of experimental and statistical methods into psychology has dealt a death-blow to the reliance that used to be placed on anecdote. In the nineteenth century, anecdote played a large part in psychology as well as biology. Studies of animals, children and savages, for example, were often based on second-hand or third-hand reports of observations made by untrained observers. Such reports, even when they gave the facts with reasonable accuracy, usually also included a good deal of conscious or unconscious interpretation, which scientific investigators often accepted uncritically. Romanes's *Animal Intelligence* consisted largely of anecdotes which had been reported to him, and which he repeated and amplified with what now appears an extraordinary *naïveté*. We have only to compare his book with those of Köhler or Thorndike to see how different from the anecdotal method is the controlled observation used in present-day investigations into animal behaviour.

III

Apart from scope and method, psychology has also advanced in practical usefulness during the period that we have been reviewing. When Ward wrote his article, he had nothing to say about the practical applications of psychology ; he treated psychology as though its whole *raison d'être* was to satisfy our intellectual curiosity about man's mental life. This view was not shared by Sully, who, as we saw, founded the Association for Child Study, and founded it chiefly for the purpose of gathering information about children that would be useful to teachers and parents. Nor was it shared by James, who thought that ' the kind of psychology which would cure a case of melancholy, or charm an insane delusion away, ought certainly to be preferred to the most seraphic insight into the nature of the soul.' But, in general, Ward's attitude was shared by his British contemporaries, and, except to a limited

extent in the educational field, applied psychology was not practised until the present century.

The First World War gave an impetus to the medical and industrial applications of psychology. The treatment of what was then misleadingly called ' shell-shock ' drew attention to the utility of psychological principles and techniques in medicine ; and the investigations undertaken to secure the health and efficiency of munition workers laid the foundations of industrial psychology. The growth of both these branches of applied psychology was, of course, also assisted by influential advocates. Thus medical psychology was much helped by British exponents of Continental psychopathology ; and industrial psychology was brought prominently to notice by Muscio, Pear and Myers—especially Myers, who founded the National Institute of Industrial Psychology in 1921. Moreover, American developments in applied psychology, particularly educational psychology, were extremely influential in fostering similar developments on this side of the Atlantic.

As a result, psychology is now being applied to many problems of practical life ; and educational psychology, medical psychology and occupational (or industrial) psychology are such well-defined branches of applied psychology that the British Psychological Society has provided each with a separate section. Nor is this recognition of the importance of applied psychology confined to psychologists. Training Colleges for teachers all provide a course in educational psychology for their students, and more and more Education Authorities are appointing educational psychologists to advise them about the psychological aspects of their work. Hospitals are everywhere developing psychological medicine, and making provision for the diagnosis and treatment of neurotic illness. And many Government and industrial organisations are employing occupational psychologists to assist them in connexion with the recruitment and selection of employees, the various psychological factors affecting productivity, and the techniques to be employed in such matters as market-research and other surveys of attitudes and opinions.

This survey has contained no reference to the growing popular interest in psychology, or to the striking change that has taken place in the status of psychology in British universities since Ward wrote his article. It has been confined to distinguishing the chief trends during the past sixty years in the scope, method and applications of psychology. From what has been said it is evident that its present-day trends are from mental experiences to the integral, psychophysical man, from cognition to motivation, from the individual in isolation to the individual as a member of society, from qualitative observation to quantitative measurement, and from pure psychology to applied.

SECTION K.—BOTANY

THE STUDY OF THE BRITISH FLORA

ADDRESS BY

PROFESSOR J. R. MATTHEWS

PRESIDENT OF THE SECTION

ACCEPTANCE of the invitation to be President of Section K of the British Association, an invitation and an honour which I greatly appreciate, implies the preparation of an address. I have chosen a subject which is obviously too large for full or detailed consideration in the time at my disposal, and perhaps I should have been deterred from the choice, when I recalled that a former Aberdeen professor, J. W. H. Trail, had dealt with the same subject in his address to this Section at the Sheffield meeting in 1910. I will only plead the passage of time and deplore the fact that after an interval of twenty-eight years his plea for the preparation of a comprehensive work on the British flora has remained unfulfilled. I have thought, also, that on this occasion a more general survey might not be inappropriate since we are meeting in an English county which has a long record of solid achievement in the study of local natural history. Hemsley, Arnold and Borrer are familiar names in the history of Sussex botany, and A. H. Wolley-Dod, well known for his work on British roses, has recently given us a very complete account of the flora of the county. To such men British botany owes a great deal.

Our knowledge of the native flora has been acquired gradually during the past four hundred years, for the beginnings of a scientific approach to its study date back to the herbals of the sixteenth century. Although the writers of these early books were preoccupied with the uses and virtues of plants, they frequently recorded observations of considerable botanical interest. Among the pioneers was William Turner, who searched for plants not only in England but during enforced absences abroad in Western Europe, where he gained an experience among continental botanists which must have made a profound impression. Although his work did not escape from the obscurantism of the period, it shows quite clearly his recognition of the need for accurate description and the importance of exact identification, requirements which are equally important now as then. As pointed out by Raven (1947), 'Turner's purpose was not to break away from the past or to rebel against tradition, but to reaffirm and defend a yet more ancient wisdom.' He collated his plants with those of ancient writers and the task which he set himself to ensure accurate identification was accepted as an essential preliminary to any further study. It is a measure of his contribution towards a record of the British flora that he refers in his several works to 238 native flowering plants, which, as stated by Clarke, 'may be considered the foundation of our British Flora.'

Two years after the publication of Turner's *Complete Herbal* (1568), the Flemish botanist, De l'Obel, who resided in England for many years, published his first botanical work from which and other of his books are obtained over 80 additions to the British list, including a substantially larger proportion of Monocotyledons than had been noted by Turner. Through one of De l'Obel's correspondents in Scotland, Cargill of Aberdeen, we learn of plants gathered in the north of Britain, including *Narthecium ossifragum* and *Trientalis europaea*, first recorded as British by Gaspard Bauhin in his *Prodromus* (1620). In 1597 appeared the famous herbal of John Gerard, perhaps the best known of the English herbalists. His attainments as a botanist are open to doubt and he seems to have transgressed the rules of the botanical code by planting *Paeonia corallina* in Kent and 'afterwards seemed to find it there by accident.' But whatever Gerard's merits as a botanist, he is credited with having added 188 vascular plants to our list, so that by the end of the 16th century more than 500 species of flowering plants and ferns, about 31 per cent. of our flora, had been recorded.[1]

This considerable achievement might well have led to the preparation of a work devoted wholly to British plants, a work which seems to have been contemplated by Thomas Johnston, whose explorations in England and Wales must have provided him with much

[1] Based on the admission of 1625 vascular plants.

of the necessary material. If Johnston did not live to write a complete flora of Britain, the records of his expeditions provide interesting additions including several alpine species such as *Arabis petraea*, *Silene acaulis*, *Saxifraga nivalis*, *S. stellaris* and *Saussurea alpina* gathered in north Wales. Altogether Johnston added 192 species to our list, some of which, however, may have been wrongly identified by later writers.

Only passing reference can be made to Parkinson, horticulturist rather than botanist, to How, the author of *Phytologica Britannica* (1650), to Merret and other 17th century botanists. Among them they contributed 115 records, bringing the total to some 820 species before John Ray emerged as the dominant figure in British botany and the most distinguished scientist of his time. Although How's book has sometimes been referred to as the first British flora, it was based largely on the earlier work of Johnston, but contained some original records communicated by friends and correspondents. In this way some relatively rare plants, such as *Tunica prolifer*, *Artemesia campestris*, *Melittis melissophyllum*, and *Ophrys aranifera* were brought to the notice of How, while *Dryas octopetala* and *Gentiana verna* were reported from the west of Ireland. By this time the pursuit of botany as a scientific study was definitely gaining ground. Exploration in the field was becoming more extensive and plants were being collected and examined as legitimate objects of study, apart from their supposed medicinal value. If How had the assistance of numerous correspondents, Merret enjoyed the advantage of having for five years a paid collector, Thomas Willisel, who did a great deal of useful work at this time in the development of field botany. He became the friend of John Ray and accompanied him on the last of his botanical journeys, when *Tofieldia pusilla* (*palustris*) was found, a species new to science, whose nomenclature and synonymy have only recently been fully unravelled by Stearn (1947). In Scotland, during the 17th century, Robert Sibbald, author of *Scotia Illustrata* (1684), devoted considerable attention to indigenous plants, recording for the first time *Potentilla Sibbaldi* and *Ligusticum scoticum*.

By the middle of the seventeenth century the period of the herbalists was drawing to a close and a new era in botanical science was initiated by Ray. Already a large number of different kinds of plants had been recognised, but their study had been closely linked to medicine, and no approach had been made towards a scientific system of classification. As every student knows, Ray's fundamental observations led to his recognition and separation of dicotyledons and monocotyledons and his pronouncements on systematic arrangement certainly prepared the way for the more elaborate systems of De Jussieu and of De Candolle, which became the basis of classification adopted by Bentham and Hooker in the monumental *Genera Plantarum*. It is true that the final scheme propounded by Ray became overshadowed temporarily by the adoption of the artificial arrangement of Linnaeus, but as Raven (1942) has aptly said, ' without Ray's preliminary work there could have been no Linnaeus.' Apart from problems of classification, Ray devoted much time and energy to the study of the native flora. His *English Catalogue* appeared in 1670, and the *Synopsis*, published twenty years later, may be said to have laid the foundations of every subsequent British flora. He appears to have examined every plant he admitted to the *Synopsis* and to have gathered most of them with his own hands. He added 217 species to the British list of vascular plants, a number that does not fall far short of Turner's contribution in the 16th century. Nor should we forget that Ray's first publication was a *Flora of Cambridgeshire*, an intimate study of the plants of a single county, which has in turn attracted the attention of a succession of Cambridge botanists—the two Martyns, father and son, Lyons, Relham, Babington and Evans. The period of prolific production of local floras was not to arrive until later, but Ray's *Cambridge Catalogue* (1660) is an early landmark in the history of county floras, and few counties can have been better or more fully explored. His wide knowledge of the English flora enabled him to provide county lists for Camden's *Britannia*, thus beginning the topographical botany of Britain which culminated in the work of H. C. Watson. By the time of Ray's death in 1705, approximately 1,030 species, or 63 per cent. of our flora, had been put on record.

In the 18th century another 205 species were added, the records derived from an increasing number of workers in the field, prominent among whom were Petiver, Dillenius, Miller, Hudson, Withering, Curtis and others including Dickson and Lightfoot in Scotland. Dillenius, first occupant of the Sherardian chair at Oxford, had come to England in 1721 and his edition of Ray's *Synopsis* remained the standard British flora until the Linnean system of classification and nomenclature was fully adopted by Hudson in his *Flora Anglica* (1762). Philip Miller, author of the famous *Gardener's Dictionary*, ' which laid the foundation of all horticultural taste and knowledge in Europe,' had likewise embraced the Linnean arrangement while Lightfoot's *Flora Scotica* (1777) and Withering's *Botanical Arrangement* (1776), which gained

wide popularity, were further attempts to co-ordinate existing knowledge of British plants with the system and nomenclature of Linnaeus. It was natural that the relative simplicity of the artificial scheme should make a wide appeal, and if it was a temporary expedient, as it was bound to be, it nevertheless dominated British botany for upwards of eighty years. A return to a more natural system as presented in the *Natural Arrangement of British Plants* (1821), by Gray, did not receive the attention it deserved nor did the proposals advanced with considerable force by Lindley meet with any immediate response.

Rebellion against the Linnean arrangement spread slowly, and during the first half of the 19th century the Linnean classes gradually gave way to natural families. In England the transition might not have taken so long, had it not been for the outstanding part played in British botany by J. E. Smith, one of the founders of the Linnean Society and an ardent supporter of the Linnean system. But if new taxonomic proposals gradually replaced those of Linnaeus we can never forget our debt to the great Swedish naturalist for the conception underlying his delimitation of genera and his descriptive precision in the treatment of species. Since the time of Darwin phylogenetic considerations have entered largely into problems of classification, but as Dobzhansky (1941) has said, ' the classification of organisms that existed before the advent of evolutionary theories has undergone surprisingly little change. . . . The phylogenetic interpretation has been simply superimposed on the existing classification ; a rejection of the former fails to do any violence to the latter. The subdivisions of the animal and plant kingdoms established by Linnaeus are, with few exceptions, retained in the modern classification, and this despite the enormous number of new forms discovered since then.'

As already indicated, the Linnean system was strongly upheld in Britain by J. E. Smith, who was responsible for the text of that voluminous work of art and science known as Sowerby's *English Botany* which began publication in 1790. A work which ran to thirty-six volumes was too large and too costly for the majority of students and the need for a smaller treatise was realised and met by Smith in the publication of his *English Flora* (1824–29). His intentions are clearly stated in the preface to the first volume. ' I wish,' he says, ' to lead young botanists to the study of genera and species, with their true grounds of distinction and definition.' As we all know, the difficulties in arriving at the true grounds of distinction and definition are often very great, but in the teaching of the subject our aim could hardly be expressed in better terms.

In his adoption of the Linnean system Smith was followed by W. J. Hooker, whose *British Flora* was published in 1830, but in the fifth edition he departed from the artificial in favour of the natural system. Hooker's *Flora*, with which Arnott eventually became associated, gained wide popularity and met with little competition until Babington's *Manual of British Botany* appeared in 1843, the tenth edition of which remains the best critical account of British plants within the compass of a small volume. Babington's work has been said ' to have revolutionised the study of British plants and to have given an impetus to thought and work among British botanists to a degree unequalled by any publication of the century.' His critical analysis might have been more readily and widely accepted but for the publication of Bentham's *Handbook* in 1858. It is unreasonable, however, to criticise Bentham because of the views he adopted as to the limitation of species, for his conclusions were not intended to be critical ; neither were they superficial. The *Handbook* was designed primarily for beginners and amateurs and as such it served and continues to serve a useful purpose. But the controversy between ' lumpers ' and ' splitters ' had begun and Babington's views were cogently expressed in the preface to the *Manual*. ' We are told that our business as descriptive botanists is not to determine what is a species, but simply to describe plants so that they may be easily recognised from a dry specimen. The author cannot agree to this rule. Although he, in common with other naturalists, is unable to define what is a species, he believes that species exist, and that they may often be easily distinguished among living plants, even when separated with difficulty when dried specimens alone are examined. . . . It seems to be our business to decide upon the probable distinctness of plants before we attempt to define them—to make the species afford the characters, not the characters form the species.' The species problem was not to prove easy although it soon came to be recognised as fundamental. The experimental method, however, as applied to problems of heredity and variation had not yet developed, the ecological approach to the study of plants had scarcely begun, nor had cytology come to the aid of the taxonomist. It was Sir Joseph Hooker who seems to have recognised the more immediate needs of students and field botanists, for in the *Student's Flora* he steers a middle course. In the preface to the third edition (1884) he writes, ' I am disposed to think that the term sub-species (which represents a stage of evolution between species and

variety) should be given to many forms considered by some as species and as varieties by others ; and that this would facilitate the better understanding especially of the larger critical genera.' When we remember that the second half of the 19th century was a period of great activity in systematic botany and that Bentham and Hooker were central figures in that wide survey of the world flora which was then in progress, it becomes all the more remarkable that these men found time to include the British flora within their orbit. Botanical exploration was at its height and a wealth of material was being examined which was to form the basis of floristic works of the first importance, to lay the foundations of plant geography and to lead to those great speculations on the origin of species which have made memorable the closing years of the 19th century.

During the second half of the 19th century British Botany was put on a sound basis ; professional botanists had played a leading part ; the third edition of *English Botany* (1863–1872) provided an indispensable work of reference and the impetus given to the study of field botany was widely felt. Enthusiasm can become infectious and workers in many parts of the country embarked on the preparation of local lists or county floras. If there followed a period of intense and almost feverish activity to secure new county records, it resulted in Britain becoming one of the best botanically explored countries in the world. Active field work deserves some reward and during the 19th century as many as 340 species, overlooked by the earlier explorers, were added to the British list, leaving about fifty more which have been recorded since the beginning of the present century.

Four hundred years have passed since the publication of William Turner's *Names of Herbes* in 1548, and thanks to the labours of generations of British botanists our knowledge of the composition of our flora may be regarded as reasonably complete. Much of this floristic work found expression in local floras, and although the 19th century excelled in their production, many more have appeared in recent years. I have no doubt in my own mind of the value of the local flora. Behind its preparation there has invariably been an enthusiastic group of workers who have devoted much time and effort to their chosen task. Their contributions are well worthy of recognition and their continued activity should be encouraged and supported. In many of these local floras are observations of great ecological and taxonomic interest and not infrequently they embody lists and distribution data relating to cryptogams as well as flowering plants, as did the works of some of the earlier writers. And I need not remind you that some of the indispensable systematic handbooks dealing with the cryptogamic plants of Britain have been written by men who made no claim to be called professional botanists.

It is indeed to the painstaking work of the amateur that we are largely indebted for a remarkably complete record of the distribution of plants in Britain. *The Botanists Guide through England and Wales* (1805), by Turner and Dillwyn, was an early contribution to topographical botany, a subject pursued with unabated zeal and energy by H. C. Watson, who enlarged the scope to include the whole of Britain. Watson was a prolific writer on the distribution of British plants, his work culminating in the publication of *Cybele Britannica* (1847–1859), in which is embodied a mass of information about their geographical relations, while his *Topographical Botany* is a more concise record of the distribution of species through the 112 vice-counties into which he divided the country for the purpose of topographical statistics. Contributions towards a *Cybele Hibernica* by Moore and More appeared in 1866, to be followed by a second edition by Colgan and Scully in 1893, and three years afterwards appeared Lloyd Praeger's *Irish Topographical Botany*. These several works and their supplements provide a very full census of British and Irish plants, which is repeated in Druce's *Comital Flora* (1932), but in view of many additions and corrections a revised edition is needed. The compilation of such a census is a laborious task and is possible only by the assistance of botanists in every part of the country. Those who carried through the initial work accomplished more than they knew, for they provided the data upon which has been based much of the subsequent analytical work dealing with the plant geography of the British Isles and the relationships of our native flora to that of the Continent.

Watson was concerned primarily with the range of species within Britain, and to this extent his types of distribution, British, English, Highland, Atlantic, etc., suffer from parochial treatment. But there can be little doubt that Edward Forbes made use of Watson's geographical classification when he wrote his famous essay on the connection between the distribution of the existing fauna and flora of the British Isles and the geographical changes which have affected their area. Forbes' subdivision of the flora into five components and his views on their relationships to the flora of Europe are well known. Recent attempts (Matthews, 1937) to analyse the flora of these islands into distinct geographical elements have likewise recognised the importance of examining the European

and extra-European range of the species concerned, but there is no complete agreement regarding their relative age within the British area. As pointed out by Cain (1944) one of the inevitable handicaps with which the plant geographer is confronted is the usual absence of any exact data regarding the age of species, and the usual absence of any proof regarding dispersal, whether long distance dispersal is possible and takes place in reality.

These questions are clearly important. The problem of relative age of species in Britain becomes all the more complicated because of the occurrence of a succession of glacial and interglacial periods spread over at least a million years. I do not propose, however, to speak of the origin of our native flora or to enter into the controversy between the 'exterminists' and the 'survivalists'. The question has often been discussed and the case ably presented from both sides ; probably neither is wholly correct. We know very little about the age of British plants, since palaeobotanical evidence of a more or less unbroken record from pre-glacial times is available for a few examples only and these are mainly aquatics. On the other hand, the comprehensive studies in the post-glacial history of British vegetation by Godwin and others are an invaluable contribution to our knowledge of the general succession of plant life in the period following the last glaciation. As further data became available over a wide area the picture will become more complete, and while the evidence in favour of the existence of relict species has been considerably strengthened during recent years, more information about the fossil record is highly desirable.

To these historical studies which deal with the past occurrence and distribution of plants should be added autecological studies in the widest sense. There is need for detailed investigations of species in relaton to the complex of edaphic and climatic factors to which any plant must be in some kind of harmony, and in relation to geographical distribution. Such studies are required not only within the general area of distribution of the species but also towards the limits of its range, and probably many of our plants have attained these limits so far as the British area is concerned. The response of a species is not necessarily the same throughout the whole of its area, but will tend to alter when a limiting factor comes into operation. This may happen even within a relatively small area, as has been shown by Blackman and Rutter (1946) in their analysis of the environmental factors controlling the growth of the bluebell, which is markedly sensitive to differences in light intensity though less affected by variations in the supply of mineral nutrients from the soil.

The work of Mukerji (1936) on the life history and biology of *Mercurialis perennis* may also be cited as an example of intensive study providing valuable information about the reactions of this species to conditions of soil and climate. Such investigations may also become a useful guide to the interpretation of historical data, unless it should happen that the biological equipment of a species changes in the course of its history. Conway's (1938) comprehensive study of *Cladium mariscus*, for example, has furnished results which are of great interest and importance. The edaphic and climatic preferences of the species have been very fully ascertained and lead to a clearer understanding of the distribution of the species in western Europe and the British Isles. The truly aquatic nature of the plant has been demonstrated by means of experiment and evidence has been advanced to show that the plant benefits by high summer temperatures and that during the winter the growing point is injured by temperatures below — 2° C. Thus the species is excluded from areas where frost is so intensive as to penetrate to the underground parts of the plant. Moreover, the post-glacial history of Cladium is especially well known in Sweden and the species can be used as a reliable indicator of climatic conditions in the past. Its abundance in Sweden during the Boreal period would suggest a warm, oceanic type of climate, and although the fossil record is far from adequate for other regions, we may agree with Conway that *Cladium mariscus* is worth some attention from field botanists, ' not only on account of its use as an indicator of climate, but because of the biological interest attaching to its reactions to environmental conditions.'

I have already suggested that many of our species may have attained the limits of their distribution in the British Isles, but there must always be some uncertainty as to whether the area of a species is expanding or diminishing, except in those cases where change is known to be taking place in consequence of altered conditions due to human activity. Good (1936) has suggested that the extension in the range of *Himantoglossum hircinum* in England may be correlated with actual changes in climatic values within comparatively recent times, and the same author has advanced a similar explanation regarding the extension northwards of *Trifolium suffocatum*. It is evident, however, that the area occupied by any species is ultimately determined by barriers to dissemination and more especially by barriers to successful gemination and establishment of its diaspores. The great variation in the reproductive capacity of plants has been fully examined by Salisbury (1942), and while some degree of dissemination

follows seed production, migration is not effected until a new individual becomes established in a new station. The area of a species is determined more by the restrictions imposed by the sum total of environmental factors than by the efficacy of its dispersal mechanism. It is not easy to explain the distribution pattern of many species except in general terms of habitat requirements. For example, *Trientalis europaea* exhibits a preference for northern pinewood communities and to this extent its distribution is influenced by that of the pine, but it is by no means confined to this type of woodland, being found also in northern beech and birch woods. It occurs also in the heath community and may ascend to 3,550 ft. Throughout its whole area, colonies of the plant are often widely separated, which may be due partly to occasional long distance dispersal and partly to historical causes. Its reproductive capacity by means of seed is low and many individuals fail to produce fruit, but the plant possesses a successful method of vegetative propagation. Experiment has shown that exposure of the seeds to low temperatures tends to promote increased and more rapid germination and this may have some significance in relation to the main areas of distribution of the species in north-east Scotland and north-east England. In Scotland the region of greatest abundance corresponds fairly closely with the isotherm for the January mean daily minimum of 33° F. *Goodyera repens* is a further example of a pinewood species with a general distribution not unlike that of *Trientalis*, but of lower comital frequency. Although the two species are frequent members of the pinewood community, their habitat requirements are not identical. Moreover, the establishment of *Goodyera* is complicated by the existence of a mycorhizal relationship, and there is no evidence that germination in natural habitats occurs in the absence of the fungal symbiont. Early stages of the protocorm may be found by careful search in the pine leaf litter where the seeds germinate, but in no case examined has the fungus been absent even from the youngest protocorms. The fungus itself is apparently more widely distributed in Britain than *Goodyera*, which would seem to indicate that the restriction of the distributional area of the orchid is not a consequence of the absence of its customary symbiont from habitats where the species might occur. There is evidence to suggest that the minute seeds of the plant may be carried considerable distances, but establishment and survival depend upon the interaction of suitable edaphic, climatic and biotic conditions. The influence of climate on plant distribution is again well illustrated in the case of *Zostera marina*, the flowering and vegetative behaviour of which, as shown by Tutin (1938), is markedly affected by fluctuations in temperature. The propagation of the plant is almost entirely vegetative, since the production of seed depends on temperature conditions which are not often realised over most of the British area where the plant occurs.

While we may confidently look forward to further detailed studies of the biology of our native plants to provide a clearer understanding of their distribution, we should also remember that the first task of the plant geographer is the accumulation of distributional data and their representation on maps. It is true that such maps are only a static phase in the science of phytogeography, but the patterns they present, whether of continuous or discontinuous types of distribution, are of considerable value; and where adequate climatic, edaphic and other data are known, correlation is often possible between distributional areas and the causes of these areas. The distribution of species in Britain and Ireland is fairly well known and fortunately one of the objects of the Systematics Association is the production of a series of maps to illustrate the geographical range of British plants. It is still customary to represent this in terms of presence or absence within vice-counties and in small-scale maps the method is perhaps unavoidable. But absolutely continuous distribution of a species is seldom if ever achieved and any approximation to this condition is the less likely to occur when a flora has suffered long and continued disturbance by the activities of man. So-called continuous areas, as Cain has remarked, are only relatively so, the disjunctions being less than the normal dispersal capacities of the diaspores. For how many British species, however, do we know the normal dispersal capacity? Pronounced discontinuity within the British area is not common, but examples are seen in *Genista pilosa*, *Vicia orobus*, *Lathyrus maritimus* and among arctic-alpine species, where historical factors are certainly involved. More generally the disjunctions in range are a consequence of environmental discontinuities arising from differences in topographic, climatic, edaphic and biotic conditions. Over any relatively wide area a species occurs only in suitable habitats and as a result of this ecological isolation the total area of a species forms a more or less complex patchwork of habitats. There are some well-known examples, of course, where the distribution area is very small and the total number of individuals representing the species very limited, but in general the boundary of an area will be differently drawn according to whether floristic or ecological data are

used. It is a laborious task to assemble information of this kind and I do not suggest it is necessary in every case, but much of it is to be found in county floras and could be used in the preparation of detailed maps where the species is of peculiar taxonomic, ecological or historical interest. A species worthy of autecological study should be mapped with as much consideration for detail as is given to its biological features. The information would be welcomed not only by phytogeographers but by ecologists and taxonomists.

The pioneers in the exploration of our flora were content with the recognition of what is commonly called the ' good species.' In the investigation of a relatively limited flora, however, a period arrives, and in the case of British flowering plants it seems to have arrived, when few ' good species ' remain to be discovered. It is then that a flora tends to become overworked taxonomically and overburdened with names. It is more than probable that a flora whose stability has been shaken in geologically recent times, not by one but by several glacial epochs, may become more difficult of taxonomic treatment than one which has evolved over a long period of time under relatively uniform and stable conditions. The vicissitudes of the Ice Age which led to the commingling of northern and southern species and the opportunity for interspecific hybridisation may well have been factors contributing to the production of that polymorphy which characterises certain genera and species at the present time. It has been said that he travels well that knows when to return, and I am not alone in believing that the time has come when we should return to a re-examination of many of our species in the light of modern developments in experimental taxonomy and cytogenetics. Of the polymorphic nature of a large number of British species there is not the slightest doubt. The advantages and results to be expected from the experimental approach to their study have been fully discussed by Turrill (1938, 1940), who points out that experiment must be concerned mainly with taxonomic units at or below the species level. The taxonomist has hitherto been obliged to rely mainly on the methods of the herbarium, supplemented where circumstances permitted by studies in the field. In general his conclusions have been sound. The need for classical taxonomy is still very great, especially in dealing with tropical floras and the revision of British genera along orthodox lines should not be regarded as having come to an end. In the critical genera, however, the methods of the herbarium have frequently led to the naming of a bewildering number of species, varieties and forms, and seem to have carried taxonomy to a point where it ceases to be useful. Many years ago I suggested (1920) that the polymorphy in the genus *Rosa* might be due to hybridisation, a view which was confirmed for the majority of British roses by subsequent cytological study by Blackburn and Harrison (1921). It is absurd to give specific names to the innumerable forms which occur within hybrid swarms as was the custom among rhodologists fifty years ago, and the modern attitude is greatly to reduce the number of recognised species.

Apart from the ' difficult ' genera such as *Rosa, Rubus, Hieracium, Taraxacum and Mentha,* which doubtless require special taxonomic treatment, there is need for an evaluation of many of those forms which have been given varietal rank. According to Druce, the number of varieties among British plants exceeds 2,600 and they exhibit many grades, but what proportion of them has a genetic basis is not known. If British genera be analysed according to the number of species they contain, it is found that most of them embrace two or more species. It is within this group of polytypic genera that most varieties have been recognised. On the other hand, 180 genera are represented by a single species ; they are monotypic within the limits of the British flora. About two-thirds of them have no recognised varieties, familiar examples being *Hydrocotyle vulgaris, Hippuris vulgaris, Glaux maritima, Menyanthes trifoliata, Adoxa moschatellina, Meum athamanticum, Sanicula europaea* and *Oxyria digyna.* Some of these species exhibit considerable variation without showing any marked discontinuity, a variation which is apparently due to environmental conditions and well exemplified by *Hydrocotyle vulgaris* or *Glaux maritima.* The relative stability of these and other monotypes may be related to a somewhat narrow ecological amplitude or to long sexual isolation. Be that as it may they offer interesting material for comparative study with more polymorphic types. Only about one-third of our monotypic species embrace one or more varieties, *Phragmites communis* and *Molinia coerulea,* for example, having each been credited with seven, but their status has still to be determined. Although the term variety has been employed in many different senses, and for this reason some writers have suggested it should be abandoned, it may often be retained as serving a useful purpose in plant nomenclature. It is probable that many so-called varieties possess no hereditary claim to such status, being no more than habitat forms or modifications sometimes of a rather extreme kind. The problem can often be resolved by relatively simple experimental research. For example, Turrill (1940)

has shown in the case of *Cytisus scoparius* var. *prostratus*, which has been dismissed by some authors, that the variety has in fact a genetic basis and at the same time shows adaptation to its wind-swept habitats. Doubtless many other varieties of British plants will prove to have a genetic basis when put to the test of experiment, but it is certainly not true for all. Simple cultivation has shown that the variety of *Trientalis europaea* named *nana* by Druce is no more than a habitat form or ecad to use a modern term. Similarly, the so-called variety *pygmaea* of *Plantago coronopus* was proved by Salisbury (1940), to be an ecad of rather extreme type related to particular habitat conditions. The plasticity of aquatic plants is well known and the variety *serpyllifolia* of *Callitriche stagnalis* may be mentioned as a further example of an ecological state. The position seems to be different in the case of *Carex pulicaris* var. *montana*, originally described by Pugsley as a forma. Experience of the 'variety' in cultivation leads me to believe that it is only an immature state of the normal plant.

There is no need to multiply examples. The British flora provides ample material for experimental research on variation within specific and infraspecific groups, and investigations need not be limited to the more obviously polymorphic types. Considerable progress has already been made in this direction and we are beginning to form a clearer conception of the composition of the generally accepted Linnean species. The well-known work of Turesson and others on the Continent, of Clausen and his collaborators in America, of Turrill, Gregor and others in this country, has been most illuminating and of immense value in stimulating further research. In the wide range of variation exhibited by *Plantago lanceolata*, Böcher (1943) recognises a number of growth-habit ecotypes which show a remarkable parallelism to those described earlier by Gregor (1937) for *Plantago maritima*. It is of interest also that some of Böcher's experimental ecotypes correspond closely, though not always exactly, with the taxonomic varieties and subvarieties accepted by Pilger in his monograph of the genus. Again, within the collective species *Viola Riviniana*, Valentine (1941) has recently demonstrated the existence of two well-marked sub-species, *nemorosa* and *minor*, which represent distinct ecotypes characteristic of two distinct types of environment, 'sheltered' and 'exposed' respectively. Nevertheless, a range of varying forms connects the two sub-species, forming an ecocline, and it is clear that for general taxonomic purposes the name *Viola Riviniana* is most conveniently used to cover a large heterogenous population, the segregation of which into numerous named forms would serve no useful purpose until their precise status can be determined by experimental research. That the ecotype may in some cases correspond to the subspecies has been claimed by Clausen *et al.* (1940), but since experimental taxonomy is still in its infancy it is perhaps too early to expect an immediate clarification of the relationship between such groups as have been variously defined as ecotype and ecospecies and the more general classificatory units employed by the taxonomist. As Turrill (1945) has pointed out in his examination of the ecotype concept, the taxonomist has no easy task in balancing morphological, ecological and genetical data before delimiting taxonomic units. For the great majority of species all the data are not yet available, but with reference to his prolonged study of *Silene maritima* and *S. cucubalus*, the same author concludes that 'it is most convenient to retain as a working basis, the ordinary taxonomic conception of *S. maritima* and *S. cucubalus* as two species separated by ecological barriers, whether genecologically one recognises them as ecotypes, as ecospecies, or as coming somewhere between the two.' In a recent discussion, Gregor (1946) expresses the view that ecotype differentiation appears to be more often continuous than discontinuous and 'continuously graded variation, especially when it involves physiological characteristics, is peculiarly difficult, if not impossible to classify along orthodox taxonomic lines.' Where variation is related to an environmental gradient the term ecocline has been suggested to denote the existence of ecotypic trends, and as already noted, the ecotype may sometimes correspond to a recognised taxonomic unit. It may be difficult to absorb the new terminology into the old, but apart from the question of nomenclature, the real value of the experimental approach lies in the emphasis which it places on the great range of variation within the Linnean species and the need for a complete analysis of this heterogeneity. Nevertheless it seems fair to state that for practical purposes the systematist with a wide range of experience is usually able to recognise those groups of discontinuities which occur in nature, groups which can be recognised and delimited as species and which are the most convenient and most important units with which the taxonomist has to work.

The physiological behaviour of species in different parts of their distribution area has already attracted considerable attention and is a fruitful field for further research. Böcher (1945) has reported that shoot and flower development in *Prunella vulgaris* and *Ranunculus acer* are apparently determined by the combined effects of temperature and photoperiodic stimulation. In south Europe

Prunella vulgaris requires warm winters and is indifferent to length of day, but farther north it flowers only after subjection to long-day conditions. The species comprises a southern (therophyte) type and northern (hemicryptophyte) types. It may be expected that investigations of this kind will eventually provide an analysis of the nature of those physiological characters which express what Good (1931) has referred to as the tolerance of species to external conditions, a character which is believed to be as specific as are morphological characters.

And this brings me to my last point—the physiological significance of polyploidy. It is well known that the number of species of angiosperms decreases rapidly from equatorial to arctic and antarctic regions, the small number of species at higher latitudes being regarded as a consequence of the severity of the climate. Though but a small proportion of species is known cytologically, the evidence suggests a relatively high percentage of polyploid species in the floras of northern regions. The flora of Iceland shows 54·5 per cent. polyploids compared with 31·3 per cent. for Sicily, while polyploid species in Spitzbergen form 80 per cent. of the flora. In Schleswig-Holstein the species of the northern element are 60 per cent. polyploid, while the figure for the southern element is 27 per cent. So far as I have been able to ascertain, the corresponding figures for the British flora are 53·9 per cent. for northern and 38·8 per cent. for southern species, although the values may prove to be different when further cytological data become available. The figures, however, serve to indicate the general position. When closely related pairs of species are considered, it frequently occurs that diploid and polyploid representatives exhibit differences in distribution; the latter commonly occur under more extreme climatic conditions. Thus there has arisen the theory that polyploids are generally better equipped than diploids to occupy rigorous and exacting habitats; but there are numerous exceptions and in the struggle for existence all diploid species have not yet disappeared. Indeed, there is no reason to believe that diploid and polyploid species should not exist together in the same or similar habitats. As Bowden (1940) has shown, a wide range of hardiness may occur in diploid species and there is no clear correlation between resistance to low temperatures and the polyploid state. In its general aspects the problem is fundamentally a physiological one, and in this connection an account of protoplasmic and other changes in the plant cell in relation to frost resistance has been given by Scarth (1944). Where the special case of polyploidy is concerned, the comparative analysis by Barr and Newcomber (1943) of diploid and tetraploid forms of cabbage is suggestive, since these authors find that the tetraploid contains a higher proportion of sugar, ascorbic acid and colloidal nitrogen than the diploid form. When the requirements of plants of severe climatic areas, often characterised by a relatively short growing season, are borne in mind, the cell physiology of polyploid species may prove to have special significance. Each species will require examination on its own merits. As Skalinska (1947) has recently demonstrated, the collective species *Valeriana officinalis* includes two types, tetraploid and octoploid, the former limited to the south and midlands of England, the latter extending to the north of Scotland. Within their respective areas the tetraploid forms are confined to dry habitats in hilly districts and are separated ecologically from the octoploids which grow at lower altitudes in moist soils. Although the higher polyploid extends farther northwards, it occupies the less exacting habitat. There is apparently a physiological differentiation separating the two types, probably representing a difference in tolerance to environmental factors under natural conditions.

When we turn from botany to horticulture, we are frequently confronted with difficulties in the cultivation of plants, which doubtless arises because of the different range of tolerance of different species. In the protected and somewhat artificial conditions of the garden many British plants can be grown successfully; but it is not always clear why some cannot. The systematic analysis of species complexes and the study of their genetic composition and of their reactions in terms of ecological and geographical distribution have much to offer to horticulture, agriculture and forestry. Important practical applications of such investigations are already widely recognised, especially in the practice of agriculture. No branch of botanical science can afford to be confined within itself. The need for collaboration is becoming more and more insistent and the distinction between pure and applied science is more apparent than real. But the advancement of science need not be determined solely by the inexorable demands of economic necessity. The natural curiosity of the human mind will insure the continued study of plants both as an intellectual pursuit and a scientific discipline. A new spirit of enquiry is abroad and is evident among professional and amateur botanists alike. The desire to learn the real facts of Nature is something to be encouraged, and the study of the British flora, in one aspect or another, offers unlimited scope and abounding interest.

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SECTION L.—EDUCATION

THE CHANGING SCOPE OF EDUCATION

ADDRESS BY

MR. W. O. LESTER SMITH, C.B.E.

PRESIDENT OF THE SECTION

I

THE shoemaker should stick to his last, and that must be my excuse for talking to you only about the administrative aspect of education. I propose to make a few comments on the way school business has increased in recent years as a result of social change and the widening scope of education.

I suppose the three leading partners in the task of administration are the Ministry, the Local Authority and the Head Teacher. Of this triumvirate, it always seems to me that the Head Teacher matters most, as in this country up to the present we have regarded the school as the natural growing point of education. So I propose to occupy the time allotted to me in discussing why the heads of our schools and their colleagues have so many more administrative duties than they used to have.

There are many signs of a managerial revolution in the realm of education, and its administration and organisation have for some years been rising in esteem. When about thirty-five years ago I began work as an education officer, I was looked down upon in Universities, public schools and endowed grammar schools as a low form of educational life. To-day I salute vice-chancellors, headmasters and even professors as fellow-travellers on the hard administrative road ; and when I ask them for a date they produce their crowded little diaries and react much as an overburdened public servant does when asked to yield a moment of his mortgaged time.

We often say that the increase of school business is due entirely to the various demands of the Ministries ; and certainly there are times when the flow of statutory orders, circulars and administrative memoranda seems to engulf us like a rising tide. But I think this is at best a partial diagnosis, and that you must probe more deeply to find a satisfying explanation. It is, for example, not without significance that the preoccupation of headmasters and headmistresses with managerial duties did not begin in schools associated with the State. Unless I completely misread its history, it began in the public schools because of their early emphasis on corporate activities and the total education of each individual pupil. At any rate, let me submit my evidence and leave you to judge.

II

Thring's diary of the eighteen sixties and seventies is full of administrative trouble, and some of his entries might have been written by a pious education officer to-day, after a frustrated morning with a school buildings committee. ' Every stone here,' he records, ' is laid in sorrow and fear, and mortared with sweat and blood and perplexity. God help us.' Miss Faithfull, following Miss Beale at Cheltenham, was appalled by the volume of school business. ' There comes,' she observed, ' to many a Headmistress a melancholy moment when direct contact with children as teacher has to be abandoned for purely administrative work.' As time went on she became more reconciled to the rôle of Martha, saying ' administration is full of interest, and problems great and small meet one at every turn.'

In 1932 *The Times* published a series of articles surveying the changes in certain British institutions during the past fifty years. They invited T. E. Page of Charterhouse to write on ' The Public Schools,' and one of his chief points is the growing deterioration of the headmaster's function. ' Once they were makers of men,' he wrote, ' but the world to-day makes other claims upon them. It does not count it their chief praise that they should be great teachers, but that they should be great organisers, men who can conduct a large outfitting establishment in a business-like fashion, with sagacity and success.'

In fairness, it should be said that Page, for reasons which I need not enlarge upon, took rather too gloomy a view of the Headmasters of his day. Some indeed strove manfully to play the dual rôle of educator and administrator,

and this was still possible in the smaller schools, especially if they were rather remote from the busy world. Mr. F. B. Malim has recently drawn for us a picture of H. G. Hart of Sedbergh, commemorated also by G. G. Coulton. 'He had no bursar,' he tells us. 'He had no secretary. He wrote his letters legibly with a pen. He was the House Master of School House, and he taught every period in the week. Whenever boys were in school, Hart was in school too. . . . In the scanty leisure left him after the correction of the Greek verse of the sixth form, Hart had to conduct his correspondence with Governors and parents, to guide his staff and rule his school.'

Still, I think we must admit that the dual rôle generally became less and less practicable as the corporate life developed, as transport brought parents nearer, and as economic problems increased. As a result the Head became less and less an educator and more and more the administrator. Mr. Tallboys, librarian and assistant master at Wellington, confirms T. E. Page's impression in his delightful book *A Victorian School*. 'The Headmaster today,' he remarks, 'is primarily an administrator; he establishes the routine of studies and the basis of order in the school, and, preoccupied with the multifarious agenda of his office, he tends to become separated from the human element in the community which he supervises.'

When early this year, Rugby chose as Headmaster an administrator without teaching experience, Sir Cyril Norwood wrote an article in *The Sunday Times* entitled 'Education in Danger.' It is part of my thesis that he was right in so regarding the supersession of the teacher by the administrator as Head of a school, but was he not a little unfair in blaming the Rugby Governors for crowning with a logical decision a process that has been gradually evolving? No one would seriously question Sir Will Spens' regard for education, least of all for its spiritual quality, but the fates are fond of irony and it was like them to arrange that the power behind the valuable Spens Report should be Chairman of the governing body which perpetrated this 'heresy,' to use Sir Cyril's epithet.

You will remember the apologia with which the appointment was announced: 'The problems which at present confront public schools are, in our judgment, such that valuable as is scholastic experience, it matters on this occasion less than other factors.' This pronouncement has an inevitable, inexorable note, and suggests what Whitehead once called 'the solemnity of the remorseless working of things.' It reads uncomfortably like a chorus ending of a Greek tragedy; nemesis has overtaken us and education has yielded to the managerial revolution.

Still, let us take heart. Some of our best colleges are presided over by men who have won distinction in the administrative sphere, and across the Atlantic when Columbia University sought a new President it elected the most highly regarded of all American citizens, General Eisenhower.

III

The Forsytes who wrote so freely to the Press about the Rugby dilemma seemed not to know that there is a parallel problem in the day schools associated with the state. But alas! it exists both in the grammar schools established under the Balfour Act and in the primary and secondary schools now emancipated from the elementary school tradition. Most of these schools have an active corporate life, and many are harassed by demands from which the Public Schools are immune. If the Education Act is to become a living force, there is need for constant creative thinking about the future of these schools; it is tragic, therefore, that at this time for greatness the heads of the schools are unable to give their whole minds to their essential task.

I do not think I am straining history when I say that we first saw the light about educating a social democracy as far back as 1644, the year of Milton's tractate; and it has taken us exactly three centuries—1944—to give legislative effect to these aspirations. As a pleasant proof of my contention, may I commend to you for light reading Charles Lamb's essay on the Old and the New Schoolmaster. The New Schoolmaster, whom he met on the Bishopsgate Coach, inspired by Milton and Comenius, has just the same dreams about active and real education as we have to-day. Why have we tarried so long? The answer, I think, will be found in Defoe's phrase 'the law of subordination,' which was still in operation in the elementary school world when I began my career. We are now rid of it—the abolition of the elementary school by the Butler Act was an historic event: let us clear the decks so that the captain of each ship—each primary and secondary school—can concentrate on its navigation.

> Where lies the land to which the ship would go?
> Far, far ahead is all her seamen know.
> And where the land she travels from? Away
> Far, far behind, is all that they can say.

Many schools are wickedly understaffed and ill-housed; so we are tempted always to discuss reform in terms of quantity. 'Let us first reduce the size of classes and provide decent healthy schools,' we urge; 'Mr.

Trevelyan, Sir Richard Livingstone and others who stress quality may be right, but what is the good of putting the cart before the horse?' So we say, but it is dangerous doctrine, for where there is no vision education perishes or at best settles down to uncreative mediocrity. Inert ideas, those mortifying tumours which Whitehead so rightly condemns, go silently about their business like the death-watch beetle. What can be done in spite of the acute material and manpower shortage to safeguard quality before it is too late? Again, Whitehead helps us. The solution of modern problems, he asserts, depends on responsible posts being held by those who can think imaginatively. So we come back to this question of the Head Teacher, his function, his creative capacity, and, above all, his use of time.

IV

There is a curious taboo in exclusive circles about the term 'Head Teacher,' but I have used it deliberately because it conveys what I regard as the function of the Head of a school. As to the extent of a modern Head's employment in educational and non-educational pursuits, it would be helpful if some competent body like the National Foundation of Educational Research would compose an analysis. My impression is that his function is changing rapidly as a result of the growth of corporate activities, the demands of society and the aftermath of government schemes.

My own observations suggest that an analysis would show that his business includes: (i) arrangements for the numerous activities of the school; (ii) interviews with parents, inspectors, the doctor, the nurse, the school attendance officer, the probation officer, the employment officer, individual employers, and various Mrs. Jellabys in pursuit of some mission which they regard as the only one in the world; (iii) national savings, school meals, and other government sponsored schemes, e.g. arrangements for the supply of milk, details for special clothing coupons, completing pension forms, release of children for agriculture, entertainments for stay-at-home holidays; (iv) projects of admirable intent, for which there is often neither the manpower nor the accommodation available other than the teacher and the school, e.g. adult and evening institutes, youth clubs, community centre, play centres, and, in areas where the production drive depends on the employment of married women, special nurseries and child care clubs; (v) other schemes, sponsored either officially or by well-intentioned organisations on the principle that once you circularise the schools the job is as good as done; (vi) the organisation of examinations, school records, and other scholastic devices often imposed externally; (vii) the reception of sponsored visitors, students for school practice or social science experience, and compilers of theses for degrees and diplomas; (viii) the completion of questionnaires, and what Dr. Spooner once called 'forming fills'; (ix) organisation of harvest camps, visits of pupils to industry, theatres and concerts, and interviews with persons interested in attracting pupils to industry, commerce or the services; (x) meetings national, regional and local: and attending one or more of those valuable refresher courses arranged by the Ministry or the local authority.

Of these and other demands, it can be said at once that some are necessary and desirable; and it is reasonable to expect their expansion with the growth of social consciousness. But some suggest the resurgence of the old law of subordination in a new guise, Demos behaving like the old feudalism writ large. Not only are schools being damaged by their constant use after hours for any and every purpose, but many a Head Teacher has to squander time daily making sure that all objects of educational and aesthetic value are safely locked away before the evening clientèle arrives.

Our schools, like the nation itself, are going through a complex process of adjustment and adaptation to a changing social outlook. They are living through a crisis. Aims and principles are in the melting pot, and every day intelligent teachers are rethinking the essential questions. At the same time new social problems press upon them urgently, and precedents are being set which affect the meaning of school and the future of education. Never was there greater need for wise school leadership.

One of the most difficult issues to determine is the extent to which schools should respond to the claims which society makes upon them. There is general agreement that, whatever may have happened in the past, they cannot to-day function in independent isolation, or, as the McNair Report puts it, teachers cannot be 'a race apart.' There is, however, a limit to the sociability of schools, a plimsoll line at which service to the community becomes a danger to education. If a service rendered by a school fits naturally into the curriculum or corporate life, the pupils may gain useful and satisfying educative experience. If, on the contrary, it is a marriage of convenience designed to further a government scheme or one promoted by an importunate organisation, there can be waste of valuable teacher-time without compensating advantage. Three examples will show how difficult it is to discriminate, and yet how vital it is to do so if quality in education is our aim.

The Land Utilization Survey of 1931 is a good example of a harmonious marriage of interests : schools were able to co-operate without disturbance of their curriculum both to the advantage of the Survey and their own study of local geography. Whether National Savings, to quote another example, makes a happy marriage, I will leave others to decide. It certainly saves money, and it as certainly consumes valuable time. I will leave it at that and pass on to my third example, School Meals, that stormy petrel of educational conferences.

The communal meal as an educative influence has a long history, and was made an essential feature of our schools when we first began to establish them. Charlemagne's friend Alcuin tells us how Albert the Wise as Master of St. Peter's School, York, in the eighth century gathered his boys around him at meal-time, and I have no doubt that William of Wykeham contemplated that the boys of his great school would learn in the refectory much that he meant by his motto 'Manners makyth man.' With such precedents to guide them, most of the ancient grammar schools took trouble to make meal-time a well-ordered corporate occasion, and it has become a valuable feature of our secondary school tradition.

In 1907 another attitude to the school meal entered our educational tradition, for in that year local education authorities were authorised to incur expenditure on feeding necessitous children. In some areas central kitchens were established, and old Sunday Schools and similar buildings were hired for use as feeding centres. During the second World War, in order to maintain child health, it was decided to feed as many children as possible ; all sorts of buildings were used for the purpose, including school halls and classrooms in daily use for teaching purposes : the emergency was rightly deemed to justify any and every kind of improvisation. Health statistics proved the value of the school meal, and the Education Act of 1944 made its provision a statutory obligation.

Alas ! owing to the scarcity of manpower and materials little has been done as yet to implement the Education Act. The crowded bad old buildings are still there, the large classes continue, and there are far too few teachers. But the school meals service has been rapidly developed and the Minister of Education recently spoke with justifiable pride of its ' phenomenal growth.' Why this priority ? The administrative answer to this question is that the free school meal is an essential feature of the Family Allowance Scheme. As a result local education authorities have been pressed—if that is not too mild a word—to expand the school meals service with all possible speed : not since John Gilpin's famous ride has there been such a breakneck gallop.

No one will deny the importance of children having a square meal, but the approach to the problem has at times shown little regard for the good life of that little commonwealth, the school. This partly explains the vehemence of the protests made by teachers at their conferences. On the other hand, no one can deny that the health of the children has benefited, and for many that will seem an adequate justification for the shock tactics employed. As Samuel Johnson once observed : ' He who does not mind his belly will hardly mind anything else.' Let us hope, however, that when the hectic race for the family allowances target is over, we shall be allowed to tackle this problem afresh without exhortations and that the school community will be free to arrange its dinner according to its way of life in its own refectory.

This is but one illustration of the many external influences disturbing schools to-day. As we have noted, some of them are inevitable, but the net result makes nonsense of our hopes and aspirations. Contrast, for example, my catalogue of intrusions with these words of Sir Richard Livingstone's : ' The prior task of education,' he remarks, ' is to inspire and to give a sense of values and the power of distinguishing what is first-rate . . . from what is not.' We cannot indulge in hopes of that kind until we solve our dilemma, and are able to put education first. Meanwhile the wounds are becoming scars, and it will be extremely difficult to rid ourselves of them. Gibbon's estimate of Diocletian's contribution to the decline and fall of Rome concludes with the pregnant observation that ' he deserves the reproach of establishing pernicious precedents rather than exercising actual oppression.' That is exactly what we are reluctantly doing, camouflaging our frequent misuse of education with arguments about the shortage of accommodation, the present emergency and so on. These arguments seem irresistible at the time, but we shall pay a heavy price for them.

In that sense Sir Cyril Norwood was surely right in speaking of ' Education in Danger.' But perhaps all that I have tried to say is best summed up in a chance comment made to me recently by a well-known Head Teacher. ' Do you know,' he said, ' I have just discovered that the boys no longer call my room " the study." They call it " the office." '

To sum up I suggest that the Head Teacher's function is changing not only because of the widening scope of education, but also because of confusion as to the rôle of the school in the new social order. We do not seem to be able to decide whether it is to

be a regenerating influence or a maid of all work. Often we unwittingly prevent the Head from using his expert knowledge of the technique of education and deprive our schools of the creative leadership they so badly need. As a result, initiative passes to a remote civil service operating through handbooks and circulars and supported locally by an enlarged inspectorate.

It is widely held that the best service education can render in these challenging days is to make good citizens. That can only be done, if, as a nation, we recognise that the essential task of each school is to educate, and that of the Head Teacher to direct and inspire his team in the conduct of an extremely difficult operation. It demands of its leader undivided attention, much human sympathy, creative ability and a scientific grasp of the intricate problems of childhood and adolescence, intensified to-day by the ethical conflicts of our time. It is a great vocation, and once we forget that simple fact we can get ready to tread the downward path.

SECTION M.—AGRICULTURE

AGRICULTURE AND THE WORLD FOOD PROBLEM

ADDRESS BY

Dr. G. SCOTT ROBERTSON

PRESIDENT OF THE SECTION

Ever since Malthus, in 1798, first published his essay on the Principles of Population, in which he put forward as a principle the universal tendency of population to outrun the means of subsistence, we have been subject to recurring doubts and anxieties as to the future of our food supplies. Malthus' views had a great influence during the early part of the nineteenth century. Later, owing to the astonishing development of transport, the advancement of science and colonisation, it became popular to treat his doctrine and views as out of date. After the World War of 1914–18 Malthus began to come into his own again and since the second World War the phrase " Freedom from Want " in the Atlantic Charter is having as much influence on world policies as the phrase " struggle for existence " in Malthus' original treatise had on the development of Biological Science.

Malthus, of course, was unaware when he published his first treatise in 1798 that we were on the verge of the greatest material revolution the world has as yet experienced.

All our material progress, as we know it, dates back 150 years, that is, to the end of the eighteenth and the beginning of the nineteenth century. It is very difficult for us to-day to grasp the perils of life 150 years ago, in the time of our great-grandfathers. Up till then the world had gone through centuries of want and famine and no material progress was possible. The human race was dependent upon hand labour and a man with hand tools can provide scant supplies for the feeding and clothing of himself and his family, let alone the soldiers, artisans and others not directly engaged in production. It was a world of constant want, almost constant war, and subject to great famines and pestilences. A conquering nation could support its people at the expense of what amounted to the extermination of the vanquished. There was no future for Europe other than the life that can be seen in, say, India and China to this day where increasing pressure of population depending on supplies of hand labour has led to increasing want and degradation.

That was the position of Europe at the end of the eighteenth century, and if you go back through the centuries which preceded, there was no ground for hope and no expectation of relief.

Nevertheless the miracle happened. The invention of machinery at the beginning of the nineteenth century, in which Great Britain played such a prominent part, the discovery and application of artificial fertilisers to the soils of Europe, and the opening up of the great continent of North America, brought about for the next hundred years or so an abundance of food. It was a period of plenty ; the fear of want and famine rapidly disappeared. In that short period of 100 to 150 years there was more material progress than in the 10,000 years which had preceded it.

What we are in very serious danger of forgetting to-day is that this period of regional prosperity and freedom from want—a period of 150 years—is a very short period compared with the 10,000 years which preceded it. Which is to be the normal future of the world, the 150 years of relative plenty or the want and even famine of the previous 10,000 years ? That is the problem which confronts us, and what the future will be depends upon the depth and width of unselfish thinking we apply to the solution.

To me this is our supreme problem of to-day—feeding the peoples of the world, or " Freedom from want "—and before we look at it there are at least two other important factors we must bear in mind. First the great increase in the world's population. For example, in little more than 100 years of relative plenty the population of Europe, despite emigration, has increased from 200 to 500 millions. In the small area represented by the British Isles the population increased from 10 millions in 1800 to over 40 millions in 1900. In the U.S.A. the population increased over 70 per cent. in the past

40 years. The same story can be repeated throughout the world even in countries like India, Persia, China, where want and recurring famine have been prevailing conditions. Orr has recently summed it up in his startling statement that the world's population is increasing by 20 millions per annum. The second important factor is the tremendous improvement in the standard of living in the more advanced countries compared with the backward countries and the declared intention of the nations of the world to make that improvement general.

Since the beginning of the twentieth century the world has once more been facing the problem of want. The period of plenty is passing, and Man, as Lord Keynes has said, does not die quietly. We have had two world wars as evidence of that fact. Butter, I hope, will always be more powerful than guns, and bread than bombs, atomic or other. The methods of production of the nineteenth century will not do for the twentieth. Gone are the days when it was possible to exchange the products of one or two industrial hours' labour for a 100 or more agricultural hours' labour. The conception of an almost entirely industrial country changing its industrial products for food is also a thing of the past.

Yet we can and we must solve the problem of feeding the peoples of the world, and it must not be a solution for one country at the expense of another.

Orr and his colleagues in the Food and Agriculture Organization have brought together invaluable information on the world's food problems—material which is of incalculable value in pointing the direction and the methods by which the problem may be solved. The solution can only come by each country doing its utmost to increase its own agricultural output. American aid can be no more than a physician's stimulant. Take the two great countries of the East, India and China, whose people in future are certainly not going to die quietly and where pestilence and famine literally stalk the land. Neither America nor Britain nor the two in combination can solve the India and China problem even if America could produce the quantities of food necessary for the purpose. Nor is it merely a matter of the ability or inability of these countries to pay for the food as such. It would be years before either of these Eastern countries could afford to accept the food even as a free gift landed at their ports. The cost of transporting it and distributing it in the hinterlands of these countries would be far greater than the peoples could afford to pay at the present time. The problem must be approached from a different angle. Keeping to the two illustrations, we must help India and China so to modernise and improve their own agriculture that they are able in a real measure to feed their own peoples. To do this these two countries require more than the present world production of fertilisers and if fertilisers constitute, as is undoubtedly the case, a cornerstone in building up agricultural production, how are we going to solve the problem ? I doubt if it can be solved by increasing production in manufacturing centres like Great Britain, and the United States, and transporting to India and China. The costs of internal distribution alone would render that impracticable. Fertiliser manufacture in these two countries and in others must form part of their industrialisation. We must help India and China towards such a measure of industrialisation as will, together with a big expansion of agricultural output, raise their economic status. Only by so doing can they and others become real partners in the community of nations and make an effective contribution to the prosperity and well-being of the advanced nations. It seems to me obvious that the future prosperity and security of the advanced nations depends upon the extent to which they succeed in fulfilling such tasks.

In coming to practical grips with the problem of feeding the peoples of the world it is, nevertheless, evident that we set off with certain very big advantages over our great-grandfathers of the eighteen hundreds ; advantages that more than compensate for the fact that there are no new North Americas to develop as a world food larder. Our great advantage lies in the startling, the incredible advance of science during the 150 years of plenty, and in the fact that the new knowledge and vastly increased power and resources which it has given us and continues to give us have, in the realm of agricultural science, only been applied and then very inadequately to a small portion of the potential crop-producing soils of the world.

If a peaceful world were to set itself the task of applying the knowledge we already have in preventing soil wastage by erosion, of increasing production by irrigation, by the application of the exacting knowledge of plant breeding, application of fertilisers, in the mechanisation of the work on the land, not forgetting the electrification of the farm buildings and homes, and by developing rapidly the application of genetical science to the breeding of our farm animals the world over, it would, at a very conservative estimate, be possible to double and even treble our production of food in a relatively short time. It is not easy to exaggerate the importance of each of these items.

Every one of us here knows from practical experience the great difference in the output

on similar land and under the same conditions from a first-class farmer and a third-class one. That is a problem for education and advisory and extension work and it is surely no exaggeration to say that by the effective application of existing knowledge in the so-called advanced countries such as our own country and the U.S.A. the present agricultural outputs would be raised by at least 50 per cent. Yet in many European countries, in the Americas and in the East there are no agricultural advisory services and little effort is made by Governments to school their peoples in modern agricultural progress.

Consider a further illustration—grass, the greatest crop of all, and which, in the Western Hemisphere, probably covers an area greater than all other crops put together. Is it not astonishing how little attention has been paid until recent times by our scientists to the supreme importance of this crop? Does anyone seriously contend that the world's grass lands and pastures are producing more than a fraction of what they could produce? We know that grass as grazed by the animal is the best feeding known for dairy cows or fattening cattle. No mixture of cereals and oil seed cakes can give us as good milk yield or live-weight gain with fattening cattle as first-class grazing. Put crudely, for these purposes all the science of nutrition cannot replace grass. What contribution does grass, the most indigenous of all crops and the best balanced feed for cattle, make to the feeding of our livestock during the winter? We must admit the answer is relatively little. We cannot stock our farms to consume all the grass at its time of maximum production, and what is conserved for winter use is mainly in the form of hay which has lost much of its feeding value. Surely we can solve the problem of conserving grass so that it may play its proper part in milk and meat production during the winter and thus minimise the competition with the human population for cereals. Whether the answer is ' dried grass ' or ' grass silage ' remains to be seen, probably both, the former on the bigger farms and grass silage on the smaller ones. But this at least seems certain, whatever the method of conserving grass it must be so mechanised that conservation can be carried through in all its stages on a 30- to 50-acre farm by a man and a boy. The problem is an urgent one, especially from a European view point. The social and political changes which in Roumania, Poland, Hungary, etc., are bringing about the substitution of the big farms by small peasant holdings means inevitably the production of less grain. The advanced European countries will not for long be able to draw to the same extent as in the past on the more Eastern European countries for cereal feeds for their livestock production. The utilisation of grass for winter livestock and resultant products is, therefore, a matter of some urgency and of great importance in minimising the competition of the animal world with the human population for cereals.

The production and conservation of grass, advisory or extension services, plant breeding, fertilisers, drainage and irrigation, the mechanisation of land work and the provision of electricity are production problems which in the main must be tackled by the individual country. Much information, knowledge and experience are available and it is for each country to determine how best to apply these to their own conditions.

Hitherto in dealing with the world food problem emphasis has been laid both by scientists and statesmen on increasing production. This is probably in the main the proper attitude, but it would be a mistake and a serious one if such concentration on production problems tended to obscure or minimise the appalling losses of crops and stock associated with food production.

World losses of crops and stock when reduced to figures are so fantastic as to create a feeling of unreality. For example, facts which the Food and Agriculture Organization has assembled in close collaboration with technical experts all over the world show that between harvest and consumption there is destroyed every year, by mites, pests and rodents, grain equivalent to all the food travelling into international trade—that is to say approximately 65,000,000 tons of grain per annum. A decrease in these losses by only 10 per cent. would mean an addition of 6½ million tons of grain available for the hard-pressed European larder and would go a long way to close the cereal gap. Science knows how to control these stupendous losses which could be quickly attenuated by the application of already proved remedial measures. Pests and diseases know no regional or national boundaries and this and many other equally serious losses of food supplies can only be dealt with by concerted action on an international basis.

The Food and Agriculture Organization would seem to be the most suitable medium for these purposes. It is an international organisation and although it cannot physically do things, has no powers in member territories and has less funds at its disposal than some United States agricultural colleges or experimental stations, yet perhaps because of these limitations it has the confidence and willing co-operation of scientific and technical experts throughout the world. In the summer of 1947 the Food and Agriculture Organization called together in London technical

experts from the grain exporting and importing countries and got down to the practical problem of concerted international action to reduce the losses due to mites, pests and rodents. The Council of F.A.O. has passed a unanimous resolution recommending member countries to take immediate and concerted action on the lines of the conference report. There is no difficulty up to this stage—but how often does action end with the passing of a unanimous resolution? F.A.O. must be provided with sufficient funds to enable it to send its experts (once the Council and the member countries have accepted such resolutions) to the countries concerned to give what assistance, if any, is needed and to report back to the Council of F.A.O. the member countries which have failed to carry out their obligations and the reasons for such failure. Unless some such modification of the machinery is brought about it is difficult to see how the resources of science already available can be brought to bear in attenuating, let alone eliminating the truly gigantic losses in world food supplies due to the diseases of crops and stock and the depredation of pests and insects.

This is but one illustration of gigantic losses of food crops. Many others equally serious and due to plant diseases could be given. But when one bears in mind that a large proportion of the world's crops are converted on a basis of about 5 to 1 into animal products and that the losses in the animal world due to disease are even more significant than in the case of crops, it is possible to get some conception of the additional food supplies that would become available if such problems were efficiently tackled on an international basis. Something effective can be done by countries like the United Kingdom which is sea girt or big countries such as the United States. The bulk of the agricultural area is, however, carved up into many small states and with diseases and pests knowing no political boundaries international action is essential. I venture to suggest that in such action lies one of the most fruitful means of adding to the world's food supplies; that the difficult supply position ahead is so urgent that we cannot continue in this matter of preventable losses of food as we have done in the past and that the Food and Agriculture Organization of the United Nations be urged to concentrate on this aspect of food supply as the greatest practical contribution which it can make to the feeding of the peoples of the world.

And now in this rather crude survey may I refer to one other aspect of the agricultural problem. There is probably general agreement with the statement that what is needed to-day and for many years to come is a much greater agricultural production. It is necessary to feed the existing population let alone the annual increase of 20 millions. But what about the improvement in the standard of living? That inevitably means a progressive increase in the consumption of animal products such as beef, mutton, bacon, eggs, milk, etc., so essential to the health of the peoples. Most of these animal products require the feeding of 4 to 5 lb. of cereals for every one pound produced. There can, therefore, be no improvement in world standards of nutrition without an immense net increase in the production of crops. Russell, in his review of the European situation (*Listener*, May, 1948) has brought this out with great clarity. The improvements which are taking place in the diet of certain countries to-day are partly at the expense of other countries in a less favourable economic position. For example, we in Britain are increasing our supplies of pig meat and eggs by importation from Poland knowing full well that these valuable supplies of animal protein are even more necessary in that country than in our own. These maladjustments will, however, continue for some considerable time in an imperfect world, and the cure can only begin to operate in the more backward countries with an improvement in economic status and a greatly increased production of the primary products of the soil.

Hitherto agricultural products—foodstuffs—have constituted only a small part of international trade. If a greatly improved nutritional standard of living is to be the birthright of the world's people, the present and succeeding generations will have to institute many changes. Agricultural produce will have to play a far more important part in world trade than in the past. The old conception of exchanging agricultural products for industrial products has already almost passed and will, I feel sure, gradually give place to a trade in agricultural products which will be mainly an exchange of one agricultural product for another—for example, the supply of processed milk to the tropical countries by those in the temperate zone in return for tropical fruits and other products. Restrictions on agricultural trade such as tariffs, quotas, etc., must also disappear. We cannot afford by such instruments to force any country into a form of agricultural production which is not suited to its soil and climatic conditions, and there can be no improvement in the nutritional standards of the peoples of the world, such as our scientists speak of and which is, if not the full embodiment, at least the trunk and beating heart of a real world prosperity, without the fullest interchange and greatly increased production of the products of agriculture.

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